THE

FOUNDRY TRADE JOURNAL

WITH WHICH IS INCORPORATED

THE IRON AND STEEL TRADES JOURNAL

VOL. 55 Thursday, July 2, 1936 No. 1037

PUBLISHED WEEKLY

Subscription Terms: 15s. per annum.
Foreign and Colonial: 17s. 6d. per annum.
All Subscriptions are payable in advance.

All Communications to be addressed to the Editor, the Advertisement Manager, or the Publisher of

THE FOUNDRY TRADE JOURNAL,
49, WELLINGTON STREET, LONDON, W.C.2

Telegraphic Address: "Zacatecas, Rand, London."
Telephone: Temple Bar 3951 (5 lines).

THE FOUNDRY TRADE JOURNAL IS THE OFFICIAL ORGAN OF

The Institute of British Foundrymen
The Institute of Vitreous Enamellers
The National Ironfounding Employers' Federation
The Welsh Engineers' and Founders' Association
and
The Foundry Trades' Equipment and Supplies Association

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Cast Iron and Fatigue

The developments which have taken place in the steam reciprocating engine, the steam turbine, and the internal-combustion engine, and the wide applications of the last, particularly for motor-car and aircraft purposes, where prime movers of great power and minimum weight are required and also for large Diesel engines, have necessitated a better knowledge and understanding of the properties of the metals used in their construction. Among the properties, which have to be considered, is that of fatigue and a knowledge of this property is essential for the purpose of modern engineering design. Most engineering structures, such as the above mentioned, are subject to fluctuating or reversed stresses or to vibration, and if failure occurs it is usually associated with fatigue of the material.

The study of fatigue phenomena has formed the subject of a large number of researches, and is still being actively pursued. These researches have dealt principally with steel and certain non-ferrous alloys, and it is only within comparatively recent years that cast iron has received the attention it deserves, possibly due to the fact that in the past cast iron has been largely used under static conditions, and that its wider application for rotating and other moving parts of machinery involving rapid and continuous reversal of stress is of more recent date, resulting from the development of high grade, high-duty irons.

The data which have been acquired have shown that cast iron has a relatively higher endurance limit in relation to its tensile strength than most other metals. Its ratio of endurance limit to tensile strength is consequently higher, a fact which is of great importance to the designer. The influence of surface finish on the endurance limit of cast iron is also small, and the effects of grooves or notches are very much less in decreasing the endurance limit than those obtained for most other materials, and also from what theoretical calculation would lead one to expect. This has been explained as being due to the heterogeneous nature of cast iron and to the fact that graphite plates may be looked upon as a series of small notches, and that one more artificial notch or scratch has little further effect. High-duty cast irons, owing to their finer graphite distribution, are more liable therefore to show a decrease in their fatigue strength, as a result of notches or flaws, than irons of a poor quality, but notwithstanding are less sensitive to such surfaces influences than steel and other metals. Cast iron, owing to its higher endurance ratio and to its lesser degree of susceptibility to surface effects, may therefore be regarded as a suitable material to withstand conditions of fatigue, provided it is found to be suitable material as regards strength, hardness, and other physical properties.

Most of the investigations on the fatigue of cast iron have been carried out in the United States and in Germany, and it is with pleasure that we note that in the series of investigations on the strength of materials under alternating stresses at present in progress at the National Physical Laboratory, three typical cast irons are to be included. A report on one of these irons has already been issued, and has shown the effect of such streses on a brittle cast iron, and we look forward with interest to the results obtained on the remaining irons, which are of a more ductile and higher grade nature.

The Chemical Engineering Congress

The Chemical Engineering Congress just concluded in London, occupied a week and was accompanied by an exhibition. It was a world affair, and served to mark the striking development of chemical engineering, involved in the large-scale production of chemical products. The Papers presented were mainly of chemical interest, but apart from those relating to synthetic resins, stoneware, and other materials of construction competitive with or likely to be competitive with cast products, those of interest to the founder were grouped in Section A, ferrous metals in chemical plant construction, which opened the Congress, although some Papers in Section B, other materials, referred also to ferrous metals. Dr. Hatfield acted as reporter in presenting these Papers, and in so doing paid tribute to the remarkable changes taking place in cast iron, and to the work in this connection of the Cast Iron Research Association. Mr. J. G. Pearce's Paper on modern cast iron in chemical-plant equipment briefly reviewed developments of interest to the chemical engineer, generally familiar to our readers, in high-strength irons, heat-resisting irons and corrosion-resisting irons, the latter covering low-alloy irons, the high-silicon irons and the austenitic irons. Reference was also made to the high-chromium irons as both heat and corrosion resisting, and particularly as offering resistance

(Concluded on page 2.)

Training of Welders

At the Twelfth International Congress of Acetylene, Oxy-Acetylene Welding and Allied Industries held in London recently, M. R. GRANJON (Director of the Office Central et Institut de Soudure Autogène) submitted a Paper on "A New Principle in the Practical Training of Oxy-Acetylene Welders," pointing out in the course of some introductory remarks that the cost of welding with a blowpipe of given power is a function of the time taken, and attention has been given to the development of methods which will make better use of the heat of the flame and increase the rate of working. Effort has hitherto been devoted rather to producing good welds than to making them quickly; also quality and speed, if not both taught at the same time, are in opposition to one another. The author has taken the view that much better results would be attained by reversing the order of the factors in training and re-training (for all old welders need to be re-trained in the new methods) and he has laid down the following principles:—

(1) A welder with a blowpipe of given power must carry out a given weld in the maximum time allotted him, this being the average or normal time determined by experience. (2) Conformity to this working time is the first of the factors to be insisted upon in the training exercises of beginners or refresher exercises of welders. The time must always be maintained even if the welds are imperfect. (3) Improvement consists in welding better and better without exceeding the prescribed working time and while reducing it if possible.

The implementing of this method at first encountered strong opposition, completely reversing as it did the principles hitherto acknowledged which required that welders must first of all learn to weld properly without troubling about the time taken. The question was asked how soon and at what stage the beginner should be expected to comply with the fixed working time, on what basis this should be fixed and how checked. It was also contended that the beginner or the welder being preoccupied with noticing the time would be deprived of the aptitude and desire to make good welds. Finally, it was said that proof that good results were obtainable by this method was still lacking.

The Chemical Engineering Congress

(*Concluded from page* 1.)

to sulphurous atmospheres. In a Paper from U.S.A. on the use of cast iron in the chemical industry, Mr. H. L. Maxwell substantially confirms all these points, but deals a little more fully with alloy irons, and illustrations of applications are given. The use of 2 per cent. chromium in the irons of the Silal type is found advantageous in some cases for heat resistance, and of molybdenum (3 to 4 per cent. with 0.25 per cent. nickel) in the high-silicon acid-resisting irons for increasing resistance to hydrochloric acid.

The chemical industry is becoming so vast that it demands and deserves materials as specialised as those available to the engineering industry, and a main difference between the two industries is that the whole of this specialised work must be undertaken by the group of independent foundries catering for the needs of the chemical industry. Some authorities in the chemical industry have compared, to the disadvantage of the iron and steel industry, the research work proceeding as a whole in the chemical and metallurgical industries respectively. The attitude of the chemical industry to research makes it very desirable that the attitude of foundries supplying them should in this respect be as enlightened and up-to-date as possible. The remaining Papers of interest in this connection will be reviewed subsequently.

The Oliver Stubbs' Medallists

MR. F. HUDSON and MR. E. LONGDEN

As it is only a month ago since we published a full biography of Mr. Frank Hudson—one of the Oliver Stubbs' medallists—we do not propose to do more in this issue than to express the high esteem in which we in common with the whole of the foundry industry appreciate the high level of his research work. In searching the files to refresh our memory of Mr. Longden's career, we found that portraits and biographies of both Mr. Longden and Mr. Hudson appeared on page 122 of our issue of February 14, 1929. Now they are linked together again as joint recipients of the Institute's highest award.

Mr. E. Longden is manager of the foundry and patternmaking shops of Craven Brothers

MR. E. LONGDEN.

(Manchester), Limited, the machine-tool makers, of Reddish, Stockport. He is a member of a well-known family of foundrymen, whose services to the industry are highly appreciated. Mr. Longden served his apprenticeship with Royles, Limited, of Irlam, and later worked as a loam moulder, making castings up to 50 tons weight, with the British Westinghouse Company (now Metropolitan-Vickers, Limited, of Trafford Park). During this period he studied metallurgy and kindred subjects under Prof. Rhead at the Manchester College of Technology. His first executive position was as head foreman to Samuelson & Company, of Banbury, and after this he held appointments as foundry manager to Tangyes, Limited, Birmingham, and the Premier Gas & Oil Engine Company, of Sandiacre, Notts. We like to think, though it may be a *lapsus memori*, that we proposed Mr. Longden as a candidate for membership of the Institute of British Foundrymen, but it so long ago (1921) that it may well have been his brother. However, since that time scarcely a year passes but the Proceedings are enriched by Papers from his pen. His type of research work is essentially rational and technical rather than academic. It possesses an equal amount of interest for both theorist and practician.

Mr. Longden has travelled extensively and has visited most of the industrial centres of the United States and Western Europe. The well-merited award of the Oliver Stubbs' medal has given to his many friends a real amount of pleasure especially those in the Lancashire area.

Art in the Light-Castings Industry

A meeting under the auspices of the British Ironfounders' Association was held in Falkirk on June 22 when the subject of the application of art to industry was discussed. SIR STEVEN BILSLAND, chairman of the Scottish Committee for Art and Industry, in explaining the object of the meeting, said that the Committee was appointed by the Board of Trade as a standing committee of the Council of Art and Industry in Scotland. Through a special sub-committee it had been investigating the question of design in relation to light castings, with particular reference to the relation of the designer to the industry and the training necessary and available to him. The Committee's conclusion was that the light metal industry offered good opportunities for attractive design, and that the sphere of the foundry draughtsman-designer might be extended and developed with a view to the production of a greater measure of original designing in the foundry and the promotion of a greater degree of executive collaboration with the architect in respect of the design of the metal fitments of building undertakings.

One had to consider, in connection with the training of the apprentice draughtsman-designer, the question of the relation between the technical training available in continuation classes and technical school or college, and the art training available in the school of art; and whether it would be well to have a design course superimposed upon the technical course or whether the two should be separate but definitely co-ordinated. They had to consider also whether it would not be advisable to set up in appropriate centres advisory committees consisting of representatives of employer, employee and educational institution, with the view to determining the precise nature of the course of training best suited to the needs of the apprentice attending the institution. The feasibility of recruiting the fully-trained student of the school of art as a foundry designer and of arranging for his technical training in the foundry, also required consideration. Sir Steven said that this country had its art and technical schools but advantage was not being taken of them.

MR. J. COUTTS MORRISON, Director of Education for Stirlingshire, thought the problem was twofold. First, there was the training of the ordinary apprentice; he thought the time had come for a revision of the work of the evening school so that it could be directed more along the lines desired by employers. The second point was the institution of day continuation classes. He expressed the opinion that every foundry in Falkirk should select one or two able apprentices and allow them, on one, two or three days a week, to attend day continuation classes in the Technical School. These boys could be trained for the industry and especially in the subject of design, so that they could be of real value to their employers. The Falkirk Technical School had been provided to train boys and girls during the day, and to see if they could make some contribution to the staple industry of the district. Something like 1,200 children underwent instruction during the day, but the other part of the scheme had been more or less a failure.

CAPTAIN H. J. KENNARD, R.N., managing director of the Falkirk Ironworks, said that little good purpose could be served in training young people to produce articles of artistic design so long as the Ministry of Health's housing policy was one of securing the cheapest possible material.

After discussion it was agreed that the Director of Education consult with the ironfounding representative on the Council of Art and Industry in the preparation of a course for both day and evening classes. A further meeting will be held in September to consider the course.

Catalogue Received

Spun Iron Pipes. The Staveley Coal & Iron Company, Limited, near Chesterfield, have issued an attractive eight-page brochure to announce that for three and four inch diameter pipes, three and four yards long, they have installed a special new centrifugal plant using metal moulds. Practical considerations have shown that it is not possible to produce three inch pipes by the sand-spun process. The brochure contains the draft of a specification covering this new line of manufacture.

The Founding of Pressure Castings*

By H. H. JUDSON,† Seneca Falls, N.Y.

[AMERICAN EXCHANGE PAPER.]

Generally speaking, engineering grey iron castings can be divided into two broad classifications, viz.: structural castings and pressure castings. The structural casting field covers those parts of apparatus which serve as frames, foundations or beds. Examples of this class are: motor and generator frames, pump and engine frames, bedplates, gear and transmission casings. The field of pressure castings includes those which, in operation, are subjected to internal pressures, such as: hydraulic pump cylinders and casings, pipes, valve boxes and pressure fittings.

Structural castings are designed from a mass and rigidity standpoint. The provision of sufficient iron to satisfy the mass or inertia requirements automatically meets the rigidity and strength requirements. The iron used in this type of casting need not be of such composition that, throughout any one casting, a close-grained homogeneous metallic structure exists. An open-grained structure in the centre of massive sections is not detrimental. There are exceptions to this, however, noticeably machine-tool beds and frames, but by and large, structural castings do not depend upon freedom from internal draws, spongy spots, coarse graphite carbon, and upon a dense fine-grained structure for their efficiency. Pressure castings, on the other hand, are quite dependent upon the absence of draws, shrinks, spongy spots, coarse graphitic carbon, and demand a dense, fine-grained homogeneous structure in order to be serviceable. The structure of the iron, as, for instance, the amount of graphitic carbon present, and, more important still, the condition in which this graphite exists, is of paramount interest in castings subjected to pressure.

Scope of Paper

It is these requirements of cast iron in pressure castings that prompted the author to accept the invitation to write this Paper. Those foundrymen, whose casting requirements are in the structural class, develop methods and techniques to cover their needs. Occasionally they are called upon to produce pressure castings, and then are apt to find that the technique developed for structural castings is not what it should be under the altered conditions. It is hoped that the foundrymen whose normal output does not include pressure castings, can glean something of value from this description of the methods used in the author's foundry. It is not intended to be a treatise on the making of high duty iron in general. Incidentally, this Paper will deal solely with pump castings.

Two Types of Mixtures

There are two distinct types of iron mixtures used in the Goulds Pumps foundry. The first type, which is in the high duty iron class, is that in which various percentages of steel rails form the major part of the charge, the balance being pig-iron and spiegeleisen. The second type is that in which no steel of any kind is used, the charges being made up entirely of pig-iron and scrap. The returns from the steel mix, or high duty irons, are used in the pig-iron—scrap mixtures for bedplates and frame parts. The first type of iron is used in all castings which are subjected to pressures above 500 lbs. per sq. in. It is also used in the larger sizes of low-pressure pumps. The operating pressures of these pumps may be low, but the overall load on large unsupported sections may be such that a strong iron is required. Pressure tightness is of primary importance, while ease of machining is secondary.

The pig-scrap mixture is used for the parts used in the small hand and power pumps in which the operating pressures do not exceed 200 lbs. per sq. in. Machinability is of equal importance with pressure tightness in this class of work. Castings for pumps which operate at pressures between 200 and 500 lbs. per sq. in. may or may not require a high duty iron. The small sizes in this range are amply strong because of low over-all loads, and the metal sections are light enough so that the cooling rate is sufficiently rapid to ensure good snug iron. The larger sizes in this range usually require a high duty iron. Machinability is not apt to be so important, in this class, yet pressure-tightness can be a problem.

That part of this class of castings which requires iron mixtures in which steel rails are used will be described first. All personal notions concerning the founding of pressure castings, in which steel rails form a part of the cupola charges, date back to 1926, which saw the inception of the two-cupola process for making high duty iron pressure-castings in the author's foundry.‡

The Two-Cupola Process

Two cupolas, one with a 54 in. bore and the other with a 72 in. inside diameter, are used to produce a high duty iron. The 54 in. cupola is used to melt charges of the following composition:—1,400 lbs. of steel rails, 4 in. or larger; 135 lbs. of pig-iron (15 per cent. silicon), and 85 lbs. of spiegeleisen (20 per cent. manganese). The tuyeres in this cupola are set 6 in. to 7 in. above the sand bottom. The height of the bed when charging is begun is 34 in. above the top of the single row of tuyeres. The cupola stands fully charged for 1½ hrs. before the blast is put on. The coke charges are 180 lbs. each, and the blast volume is kept at about 5,500 cub. ft. per min., with 12 to 16 ozs. blast-pressure. Tapping is continuous, and the spout is of the skimming type.

All of this iron is tapped into one ladle, and will yield the following average analysis: T.C., 2.40; Si, 1.35; Mn, 1.0; S, 0.11, and P, 0.13 per cent. In the meantime the 72 in. dia. cupola is melting, for normal production work, the burden consisting of pig and scrap iron, a soft iron of the following analysis:—T.C., 3.25; Si, 2.40; Mn, 0.55; S, 0.10, and P, 0.35 per cent. A predetermined amount of this soft mixture is run into a crane ladle, suspended from a crane scale, and is then poured into the ladle containing the hard iron from the 54 in. cupola. The resulting analysis of this mixture on the basis of 4 tons of hard iron to 1 ton of soft iron is roughly as follow:—T.C, 2.50-2.65; Si, 1.50-1.70; Mn, 0.90-1.10; S, 0.11-0.13, and P, 0.15 per cent.

This iron is used for castings that operate at pressures up to 1,500 lbs. per sq. in. on oil, and petrol, and which are tested up to 3,500 lbs. per sq. in. These castings weigh from 500 lbs. up to 3,000 lbs. The wall thickness of these cylinders, valve boxes and piping details, average from 2 to 2½ in. in thickness, with valve deck sections as thick as 3 and 4 in. Like other irons of this type it shows a markedly uniform structure across a fracture. Fig. 1 shows a cylinder, weighing 2,300 lbs., that was tested to destruction, failing at 6,000 lbs. per sq. in. pressure. Fig. 2 shows the structure of this iron at 100 magnifications, etched, and Fig. 3 is the same specimen at 500 magnifications.

The tensile strength, taken from test specimens cut from the walls of actual castings, runs from 17.8 tons per sq. in. up to 21.4 tons per sq. in. The Brinell hardness varies from 207 to 217. A standard 1¼ in. dia. test bar is grey throughout, and castings as thin as 1 in. in wall section are quite readily machinable. If

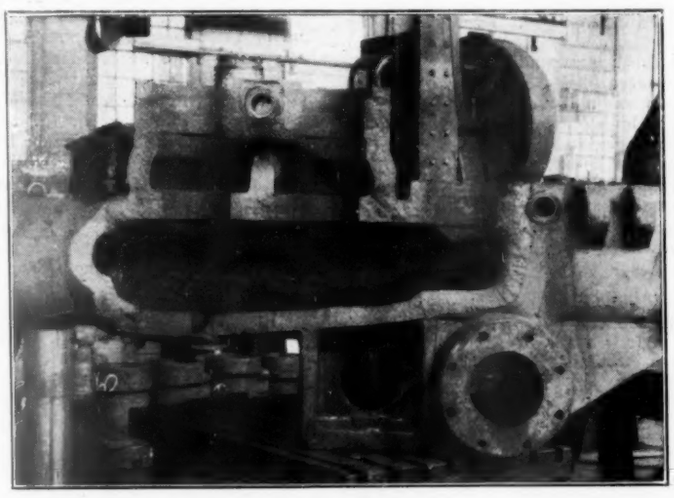

FIG. 1.—LINE PUMP CYLINDER, 2,300 LBS. IN WEIGHT, TESTED TO DESTRUCTION AT 6,000 LBS. PER SQ. IN.

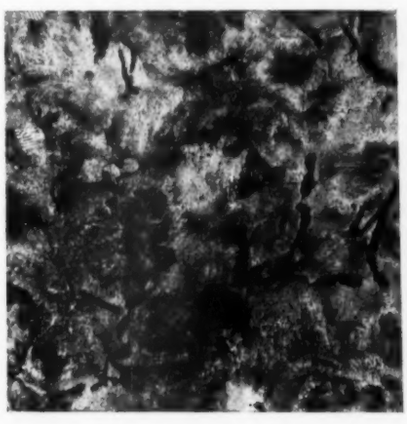

FIG. 2.—TWO-CUPOLA IRON. ETCHED. × 100.

* Paper presented at the Annual Conference of the Institute of British Foundrymen in Scotland last month.

† Foundry Superintendent, Goulds Pumps, Inc.

‡ "High Test Iron for Pressure Castings," A.F.A., Vol. 40, pp. 153-167, 1932.

there be any white iron in the fracture of the 1¼ in. bar it is a definite indication that the iron is "off-grade." Two heats were made, accidentally, with the silicon at 1.23 and 1.28 per cent. The iron was lifeless, freezing on the lip of the ladle, and showed a white net work in the fracture of the arbitration bar. It was then found that more than a charge of 15 per cent. silicon pig had remained in the drop, which accounted for the low silicon. A return to the charging scheme that would ensure bringing all of this silicon down into the ladle eliminated the trouble.

For the above reasons it is felt that 1.40 per cent. silicon is the lower limit for an iron running 2.50 to 2.70 per cent. total carbon. Silicon, in the cupola charge, is a splendid deoxidiser, and exerts a softening effect through preventing excessive oxidation. In an attempt to force the carbon still lower than 2.50 per cent., a heat was run with the bed and coke charge lower than standard, but with normal blast and metal charges. The carbon dropped to 2.34 per cent. and the silicon to 1.39 per cent., with the manganese at 0.77 per cent. The heat was a total loss. The melting conditions were such that iron was actually burned in the cupola. The charging door resembled a huge fireworks sparkler. The iron was lifeless, shrunk badly and showed a dead white fracture in a 2 in. dia. pouring sprue. Strangely enough, this runner was readily machined with high speed steel, a tensile piece cut and threaded from it failed at 20.6 tons per sq. in. It is felt that with the method described the low limit of carbon is 2.40 per cent., as there have been produced successful heats with the total carbon just under 2.50 per cent.

Considerable relief from rejections, because of leaks, internal draws and shrinkage on high-pressure parts and also from low-bursting pressures has been had from the use of the two-cupola iron. This is true to such an extent that the process and data deduced from it have influenced personal practice with the high duty irons melted in one cupola. Attempts were made to produce a similar iron in one cupola, the 54 in., but with varying degrees of success. The same materials were used, but a charge of soft iron equivalent to that which would ordinarily be used in the molten condition was added to the steel-mix charges. These additions were made in several different ways. The results never reached standard. The heavy-walled high-pressure castings were apt to sweat at test-pressures of 1,000 lbs. per sq. in. and upwards, at points where fins or flash had been chipped off, indicating a coarser structure. The graphite was coarser, as shown by photomicrographs. The possible reasons for this graphitic condition are given later in this Paper. However, enough satisfactory heats were run to indicate that a technique can be developed that will be quite as successful.

Conclusions on Two-Cupola Process

The fundamental notions as personally envisaged in the two-cupola process are as follow:—

(1) The materials charged into the 54 in. cupola are almost entirely free of carbon in the graphitic form, and the carbon content of the charges is low. These conditions, coupled with others, make for a finely-divided graphite.

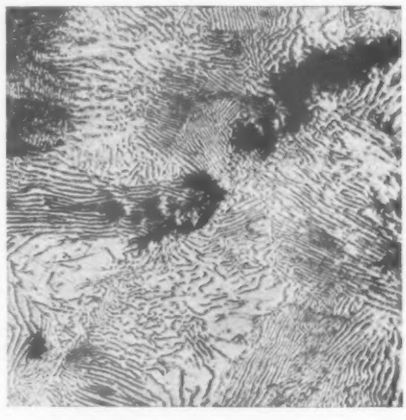

FIG. 3.—TWO-CUPOLA IRON. ETCHED. × 500.

(2) The iron has a low carbon content, which is conducive to high strength, early freezing and a uniformly fine-grained structure.

(3) The best results have always been obtained when this iron has been melted hot and poured as hot as possible. The hotter a cupola-melted iron is poured, the quicker and more uniformly it cools through the freezing range.

Materials Used

The first of these fundamental notions deals with the materials used. The steel rails, spiegeleisen and high-silicon pig which are charged into one cupola, contain no free graphite. Therefore, there is none to be dissolved. Shortly after this system was started in the author's foundry, Piwowarsky's Paper entitled "Production of High Test Iron" was published. On page 956 of the 1926 A.F.A. Transaction he states:—

"I have, therefore, proposed a simple method for producing high-test cast iron, in which all pig-irons—even those with high silicon content—are specified to the furnaces on purchase, to be machine cast; and, if possible, to be water-chilled in addition, irrespective of what they contain. If the melting process in cupola, air furnace or electric furnace is carried through sufficiently rapid, the carbide will nearly all remain intact and go into solution in the melt, and a result is obtained similar to that when the molten metal is given an extended superheating treatment. That is, there is less undissolved graphite remaining in the molten iron. Such iron will then set under conditions of greater spontaneous temperature drops below the freezing point."

This molten hard iron, therefore, partakes of the virtues of a superheated iron. However, it is too hard for any of the grade of castings under consideration, and has a high shrinkage, with little or no graphitisation. This hard iron properly melted has plenty of molten life, as sand-blast nozzles and Sandslinger tips are cast from it with no trouble from mis-runs. The soft iron added provides the softening elements necessary, that is, the graphite nuclei and some silicon. Incidentally, in order to retain the benefits of a superheated iron, the soft iron is added to the hard iron as late as possible in the process so that the graphite structure will not be coarse.

High- and Low-Temperature Experiments

This premise is based on a personal experience of four years ago. Since this high test iron is poured quite hot it punishes the dry sand moulds and cores severely. The iron was held, in order to cool it, for 20 mins. before pouring, on two successive days. The cylinders from both heats burst at ordinary testing pressures. Tensile specimens were cut from the walls of the cylinders and were tested. There was a decrease of from 5.4 tons per sq. in. to 6.7 tons per sq. in. in strength, as they broke at 14.3 tons per sq. in. to 15.6 tons per sq. in.

The chemical analyses were satisfactory. However, a microscopic examination at 50 dia. showed a vast difference in the graphite structure. The graphite in the dull-poured iron was very coarse, which no doubt accounted for the decrease in strength. Fig. 4 shows the graphite, at 50 dia., of a satisfactory iron. The sample was taken from the 2 in. wall of a cylinder, poured as hot as possible. Fig. 5 shows the graphite, at 50 dia., in a sample taken from the same location as Fig. 1, only from a cylinder poured on the dull side. The iron had been melted hot, but was cooled down in the ladle. Then an examination of the fracture with a low-powered magnifying glass, three or four dia., showed small rounded dark grey patches in a normal silvery grey matrix.

Di Giulio and White, in their Paper "Factors Affecting the Structure and Properties of Grey Cast Iron," A.F.A. Transactions, 1935, cover the

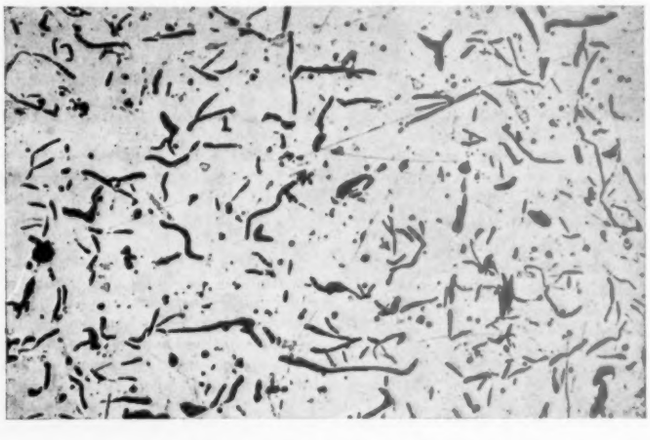

FIG. 4.—CYLINDER IRON POURED HOT. GRAPHITE AT 50 ×.

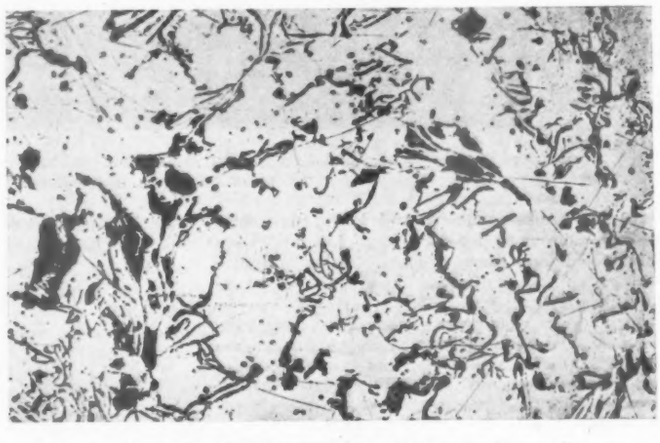

FIG. 5.—CYLINDER IRON POURED DULL. HELD IN LADLE 20 MINS. GRAPHITE AT 50 ×.

subject adequately. They report on tests to show the effect of pouring temperatures on the structure and properties. Heats were run at various degrees of superheat, in a 250-lb. electric furnace. A group of bars was cast at the maximum temperature of each heat. The balance of each heat was then allowed to cool down in the furnace, and at intervals more bars were cast. The time elapsed between the pouring of the first and last group of bars from each heat never exceeded 35 mins.

Physical data and photomicrographs were taken, upon which they comment as follow:—

"The results of this series of tests . . . . show that for all irons that have been investigated an optimum pouring temperature exists, that above this temperature there is a slight decrease in physical properties, and that below this temperature the decrease is of much larger magnitude.

"Photomicrographic study was made of representative sections of all of these irons. However, it was thought sufficient to report the typical appearance of only one of them. . . . In the iron poured at 1,665 deg. C. the graphite flakes are smaller and more evenly distributed throughout the matrix than in the iron poured at 1,358 deg. C.

"Apparently, the time during which cooling took place permitted some of the large flakes to partially dissolve and thus decrease in size. As the pouring temperature is further lowered below 1,426 deg. C., the size of the graphite flakes becomes larger. This process continues as cooling takes place until 1,358 deg. C. is reached, when the finely flaked graphite has almost disappeared. The rather large patches are predominant, and the elongated flakes are much longer and thicker."

Hence the soft iron is added to the hard iron not more than 5 mins. before pouring is begun. The mixture is then poured promptly with as little reduction in temperature as possible. An optical pyrometer reading indicates an apparent temperature of about 1,398 deg. C., or actual temperature around 1,482 to 1,510 deg. C. at the spout of the hard iron cupola.

It is thought from personal experience that low total carbon, *i.e.*, from 2.40 to 3.00 per cent., is desirable in unalloyed iron, for high pressure work, since it promotes a fine-grained structure both as to matrix and graphite, so necessary for pressure-tightness and strength, if poured between 1,426 deg. C. and 1,482 deg. C. actual temperatures. This it is admitted is about as hot as it can be melted in a cupola. It makes for uniformity of structure in varying wall sections, as judged from examination of the fractures of several hundred heavy-walled cylinders. Its freezing range is such that, with proper risers, shrinkage and spongy spots are readily avoided. When sections do not exceed 2 in. in thickness risers can be eliminated.

Risers, Chills and Chaplets

If risers be used, they must be large enough to feed the casting without pumping or churning with a rod. Churning feeding heads in low-carbon iron mixtures in personal experience is actually harmful. The juncture of the riser with the casting always showed large, open shrinkholes. Incidentally, it was learned several years ago that the use of chills or denseners, as well as chaplets and anchors on low-carbon iron castings, was detrimental. Even though the denseners used on internal cores in a large cylinder were quite light as compared to the wall section against which they were used, a fine hair-line chill was formed on the inside. This reduced the bursting pressure of the cylinders tremendously. An improvement in melting conditions removed the need for the risers, and the use of chills. Chaplets and core anchors are apt to produce blow-holes in the castings. Evidently the metal begins to freeze at such a high temperature and develop the mushy state so early in the cooling cycle that the gas formed, when the iron strikes the cold chaplets, is not released by the metal. It is personal practice to bolt all cores down or hang them in the cope. It is only on non-pressure sections of castings and un-machined parts where anchors and chaplets are used.

Any fluttering of the iron against the mould or core is detrimental for low-carbon cast irons. The gas formed is usually trapped in the casting. Thus all core sand and moulding sand mixtures must be open and free-venting. Several so-called "shrinkage" problems were solved by the use of a vent wire.

Low Total Carbon Content

The second fundamental notion in connection with the two-cupola process deals with the low total carbon content. The lowering of the total carbon is brought about in the cupola by the use of steel rails in the charges which are melted under the following conditions:—

A low bed is used so that the molten iron has less coke through which to pass and absorb carbon. Incidentally, there may be a slight tendency towards an oxidising condition with a low bed, which makes for a reduction in carbon in any mixture. The by-product coke used is a very dense grade, and its analysis is:—Fixed carbon, 91.5; volatile matter, 0.90; ash, 7.7, and sulphur, 0.58 per cent. It is slow burning and holds up well. The coke charges are low compared with the figures given in other Papers written on the subject of melting a high steel charge in the cupola. The blast used is normal. Evidently this dense, slow-burning coke, coupled with the blast used, maintains the bed at a low point, without dropping it too low. In the pig-iron—scrap iron mixtures a definite decrease in the total carbon content has been noticed. For years it approximated 3.50 per cent. when using a bee-hive coke. Since a by-product coke has been used the carbon has gradually decreased, to between 3.25 and 3.30 per cent. Three different brands of by-product coke were tried, each succeeding brand being denser—that is heavier per unit volume—than the preceding. Each change brought with it a lowering of the total carbon. The present coke is the densest and gives the lowest carbon, possibly because the furnace can and does use less of it per charge, by weight, than any of the others. Thus the grade of coke as well as the bed height affects the total carbon.

The tuyeres are set close to the sand bottom, *i.e.*, 6 to 7 in. above it. Thus the amount of coke below the tuyeres is held to a minimum, and the iron has still less coke through which to pass. Because the tuyeres are set so close to the bottom the tap must run continuously. As fast as the iron melts it is withdrawn from the cupola and also from the carbonising influences of the coke in the well of the cupola. The iron spout is of the skimming type, for the removal of the slag.

Pouring Temperatures and Pouring Practice

The third fundamental notion is that pertaining to the pouring temperature. Incidentally, what follows covers the pouring practice used on the complete range of pressure castings. All low carbon high-test iron castings are poured as hot as possible, *i.e.*, no time is lost between tapping out and pouring the moulds. It is a personal belief that the hotter the cupola-melted metal is poured, the finer and more uniform the grain structure and the greater the freedom from internal defects and chilled corners. Most of the investigational work done on the effect of superheating cast iron on its physical properties has been done in the electric furnace. The temperatures reached in these experiments are much higher than those obtained in a cupola. The cupola is poured at about 1,455 deg. C. actual temperature. This is approximately the best pouring temperatures for superheated electric furnace irons, *i.e.*, an electric furnace iron superheated to 1,537 deg. C. and 1,593 deg. C. will give its best physical properties at a temperature between 1,426 deg. C. and 1,482 deg. C. Thus starting off with a cupola-melted iron in which the carbon is completely dissolved and at a temperature about 1,480 deg. C. some of the benefits of an electric-furnace refined iron are obtained.

There was a period, several years ago in the author's foundry, during which all castings, large and small, for heavy and light pressures, cast in green sand and dry sand, were poured on the dull side. If the metal was hot it was chilled down by adding scrap to the ladle. Then with no other changes, as far as iron mixture, sand, moulding, gating, etc., are concerned, there followed a period during which all moulds, both green and dry sand, were poured as hot as the iron could be taken to them. The machine shop losses from leakers, dirt, shrink and spongy spots, decreased so suddenly that it served as conclusive proof that hot pouring is essential to pressure-tight castings. The improvement in the machine shop results was so marked that hot pouring is now almost a religion.

Professor G. B. Upton, in his book, entitled "Materials of Construction" notes that:

"If the metal be poured 'cold,' the outer part of the casting cools sharply, in heating up the mould, and the centre cools very slowly during freezing. If the metal is poured 'hot,' the mould will be thoroughly heated long before freezing, and the piece will be cooling rapidly throughout during freezing."

Reference to the cooling-rate curves of steels quenched in various liquids shows that the idea behind the above statement is that an appreciable length of time has passed, after pouring before the establishment of the temperature gradient that governs the cooling rate of the casting, especially the rate through freezing. Pouring near the freezing temperature, brings about a quick freezing of the skin of the casting, by heating up the cold mould, but does not provide the necessary temperature difference between the metal and the mould to establish a steep temperature gradient when freezing is approached. Thus the interior of the casting cools relatively slowly. On the other hand, pouring hot heats up the mould and only a very slight skin is formed, leaving the interior still molten and at a sufficiently high temperature so that when the freezing temperature is approached a steep temperature gradient has already been established and relatively rapid freezing occurs.

Fig. 6 and 7 represent, schematically only, the time-temperature relationships in the cooling of two similar castings, one poured from dull metal and one poured hot, from the same ladle of iron. These curves are typical of cooling curves of quenched steels. The skin temperature drops very rapidly down through the freezing range and beyond. The centre does not decrease in temperature at the start. Soon, however, this decrease in skin temperature sets up a temperature gradient between the skin and the centre. The skin then begins to draw heat from the centre, and the decrease in temperature of the skin to the mould is retarded. The centre is now cooling and increasingly greater cooling rates are being established as the time interval after pouring increases.

In the case of the "dull" poured casting, Fig. 6, the casting is poured just above the freezing range, thus before sufficient time has elapsed to permit the development of a rapid cooling-rate, the casting has begun to freeze. The skin has already passed through the freezing range at a very rapid rate, and therefore shows a fine-grained structure. The curve representing the casting halfway between the centre and the skin indicates that the casting is cooling less slowly through the freezing range and will show a coarser structure than the skin. The centre is cooling still more slowly through the freezing range and will have a still coarser structure. There has been insufficient time for the casting

to set up a steep temperature gradient in the freezing range so the result is slow freezing and coarse graphite.

Fig. 7 represents a similar casting poured "hot." The skin freezes very rapidly at the start but not as rapidly nor as deeply as in the "dull" pour. Then the centre section begins to feel the effects of the decrease in skin temperature and it begins to cool also. This beginning of the centre to cool occurs high enough above the freezing range to permit of the establishment of a steep temperature gradient so that as the freezing range is approached the maximum rates of cooling have been established clear to the centre of the piece. Hence relatively more rapid freezing of the centre of the casting occurs, resulting in a finer grained structure.

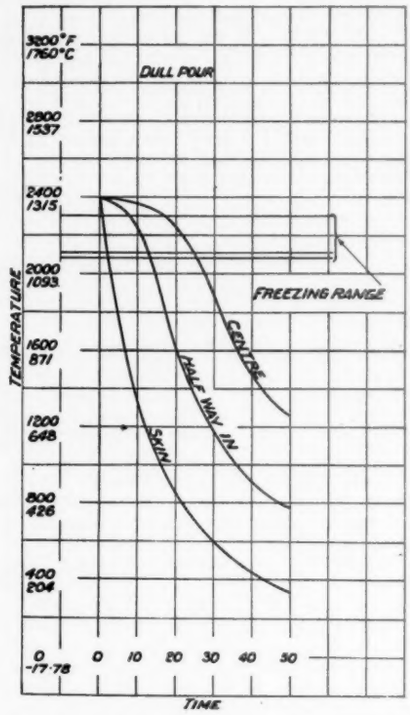

FIG. 6.—TIME-TEMPERATURE RELATIONSHIP OF THE COOLING OF A CASTING. (SCHEMATIC ONLY.)

Reference to the curves of both Figs. 6 and 7 shows that in the "hot" pour the cooling rates inside the piece are not only faster but they are more nearly uniform than in the "dull" pour. Fig. 8 shows schematically the relative cooling rates of the various sections of the hot and dull poured castings, in the freezing range. The cooling rates are merely numbers representing the slope of the cooling rate curves of Figs. 6 and 7 in the freezing range. The greater uniformity of the cooling rates in the "hot" pour over the "dull" pour is noticeable, as are the faster cooling rates.

The practical demonstration of the above views on the effects of pouring temperature on the rate of cooling in castings is shown in the quenching of steel. Given two pieces of steel of identical analyses, one of which is ½ in. diameter and the other 3 in. diameter, to be hardened. The ½ in. piece can be quenched just above the critical temperature and it will be hard throughout. It will be hard throughout, because the cooling rate of this small piece is sufficiently fast. The 3 in. diameter piece must be heated to a much higher temperature before quenching in order to get the hardness throughout the piece. The higher quenching temperature for the heavier piece is necessary so that the time necessary to develop the required speed of cooling for the hardness to extend throughout the piece is available.

Practical experience has shown that results bear out the above theory, at least, for the cast irons melted in the cupola. Since the rate of freezing affects both the amount and size of the graphite particles and since hot-pouring will cause rapid freezing, which in turn makes for a fine-grained structure, all of the pressure castings made by the author are poured on the hot side.

Di Giulio and White state also, in their summary of findings:—

> "Cast iron poured from too low a temperature shows excessively large flakes. The reason for this is to be found in the fact that pouring from such a low temperature will result in a slower rate of cooling in the moulds which permits graphitisation to occur to a great extent. The formation of large graphite flakes effectively breaks up the continuity of the matrix, thus producing weak iron."

Referring again to the experience which obtained in connection with the holding of iron in the ladle for cooling. Adding the soft iron to the hard iron provided the graphite nuclei necessary to promote coarse graphitisation. Holding the mixture provided ample time for any agglomeration of the graphite that might take place and brought about the low pouring temperature. It is felt that the one-cupola process produces heterogeneous results because the soft iron, both in the solid and liquid forms, carries graphitic carbon into the mixture too early in the process. If this soft iron could be obtained in the chilled form (that is, with the carbon mostly in the combined form in the pig) better results would be yielded.

One-Cupola Process

As was stated earlier, the good results obtained with this two-cupola low-carbon iron led to the closer consideration of the common one-cupola steel-mixes. These one-cupola steel-mixes, charged in the cupola first and therefore tapped out first, to avoid as far as possible the mixing with the soft-iron charges which follow, are used in pump parts which operate at pressures between 200 lbs. per sq. in. and 1,000 lbs. per sq. in.

Charges.—The charges for these steel-mix irons, or high-duty irons, melted all in one cupola, contain from 30 to 60 per cent. steel rails, 3 per cent. spiegeleisen and the balance pig-iron, one of which contains 2.25 per cent. Si and the other 3.50 per cent. Si. No scrap of any kind is used. The amount of steel used is governed by the wall-thickness of the castings to be poured. The thicker the wall section the lower the total carbon required, and, therefore, the more steel rails per charge. This particular notion works out satisfactorily when relating to castings up to 2 in. thick. The silicon content, determined by the pig-iron used, is governed also by the wall thickness, from the machinability standpoint. The total carbons of the various mixtures vary between 2.80 and 3.25 per cent., and the silicon content between 1.50 and 2.00 per cent. The machinability of a ladle of iron for the particular jobs to be cast is determined by the depth of a chill in a small bar, 1 in. by 2 in. by 6 in. cast open-sand, against a chill bar. The thicker the wall section, the greater the depth of chill that is desired.

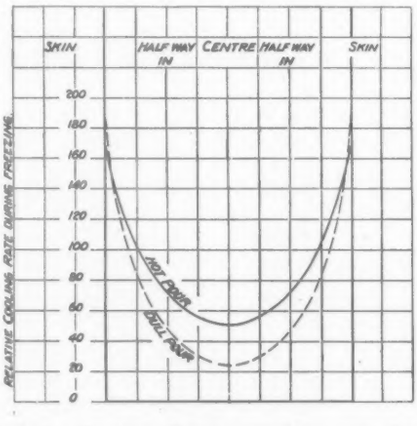

FIG. 8.—COOLING RATES THROUGH THE SAME TEMPERATURE (FREEZING RANGE). (SCHEMATIC ONLY.)

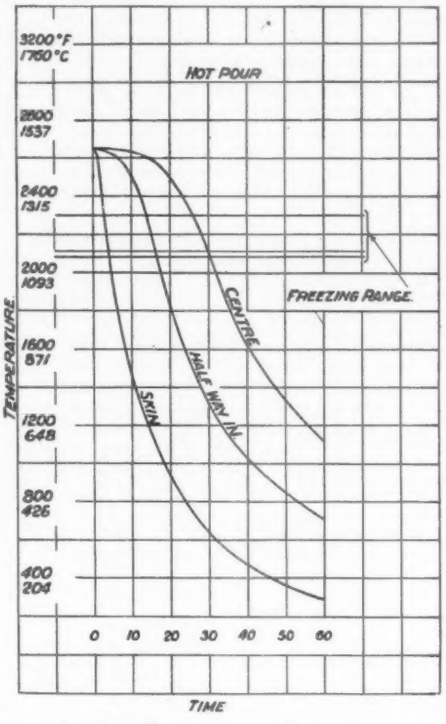

FIG. 7.—TIME-TEMPERATURE RELATIONSHIP OF THE COOLING OF A CASTING. (SCHEMATIC ONLY.)

Control of Chill Depth

Formerly the various depths of chill were obtained by using a fixed steel percentage in the charge and varying the silicon content. In other words, the total carbon was reduced to a more or less fixed point, by using the same amount of steel rails in each charge, while the silicon was varied. When a deep chill was sought, the silicon was lowered and when a light chill was needed the silicon was raised. One objection to this system was that the chill tests were apt to be erratic. The low-silicon mixtures, intended for deep chills, and therefore heavy-walled castings, were apt to give trouble. The machine shop would report certain castings as being hard, and they were very hard, even though the chill test for that particular ladle indicated that the analysis was satisfactory. The leakers were definitely higher at that time also.

The present method is to vary both the silicon, which is about 50 points higher than formerly, and the total carbon. The chill tests are less erratic with these mixtures. Experience has shown that the heavy-walled castings from 1¼ in. up to 2 in. thick, give best results on the pressure tests at 1,000 lbs. per sq. in. when the total carbon is 2.80 to 2.95 per cent., *i.e.*, a little below 3.00 per cent. The silicon is then controlled at 1.50 to 1.80 per cent. Incidentally, personal experience checks closely with that of other workers in that the lower-carbon cast irons are not affected, as to unit strength and grain size, by rather appreciable variations in silicon. In the two-cupola process the silicon has been as high as 1.80 per cent. when the standard has been 1.50 per cent., without any apparent ill-effects from softness and excessive graphitisation. Decreasing the total carbon content of an iron mixture, everything else being equal,

tends towards making the iron freeze as white iron. However, raising the silicon, in this lower carbon iron offsets this tendency. Incidentally, the ferrite formed is stronger because of the increase in silicon.

Fig. 9 shows an eight-stage centrifugal pump now operating at 1,000 lbs. per sq. in. on petrol. The lower half-casing weighs 2,000 lbs. and the upper half weighs 1,400 lbs. The analysis of the iron is these castings is:—T.C., 2.9-3.0; Si, 1.65-1.8; Mn, 1.04; S, 0.12, and P, 0.15 per cent.

They do not leak when tested with kerosene at 1,600 lbs. per sq. in. pressure. They are operated at 1,000 lbs. per sq. in. on oil and petrol so they must be quite free from internal defects of all kinds. The heavy parting flanges

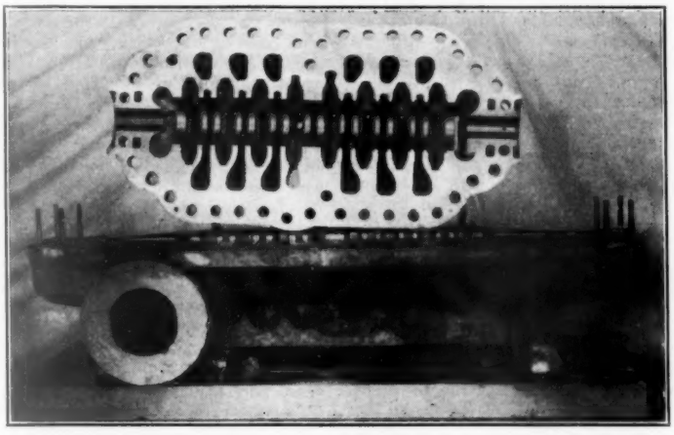

FIG. 9.—SIX-IN., 8-STAGE CENTRIFUGAL-PUMP CASINGS OPERATING AT 1,000-LB. PER SQ. IN. PRESSURE ON PETROL.

are 2½ in. thick, as cast, the wall thickness of the volutes is 1½ in. and the partitions between the various stages are ¼ in. thick, as cast. The cored passages are intricate and the sections vary abruptly all through the casting.

As the wall sections decrease in thickness, the total carbon is increased by decreasing the percentage of steel rails per charge. The silicon may or may not be increased, depending upon the amount the total carbon is reduced. Castings measuring ¾ in. in thickness and tested at 500 lbs. per sq. in. are run with iron analysing 3.00 to 3.20 per cent. total carbon and silicon at between 1.85 and 1.90 per cent. Small parts that are from ½ to ¾ in. in sections are poured with a mixture analysing 3.15 to 3.25 per cent. total carbon and 1.90 to 2.00 per cent. silicon.

Compared with the practice of 7 or 8 years ago, the present high-duty iron practice calls for mixtures in which the silicon contents range from 40 to 60 points higher and the total carbon from 25 to 75 points lower. The object sought by the use of higher silicon in the low carbon cupola mixes, is that, it can serve as a deoxidiser in the melt, and it also serves to prevent the low carbon irons from freezing out white.

Some experiments were run recently with all scrap mixtures in a 30 in. cupola. Silicon was added to the charge in the form of cement briquettes during one series. In the next heat a comparable amount of silicon in the form of lump and powdered 90 per cent. ferro-silicon was added to the ladle. The iron was cast in chill moulds. The analyses from the two heats showed:—

Nature of heat.	T.C.	C.C.	Si.
Briquettes in cupola ..	3.40	0.34	2.20
90 per cent. Fe-Si to ladle..	3.32	1.07	2.15

The results were doubted and checks were made which were substantially the same as the original. Evidently the addition of silicon to the charge is more potent as a graphitiser, possibly because of its deoxidising qualities. It is felt that if the total carbon be lowered so that the silicon can be controlled at say, 1.75 per cent., instead of 1.25 per cent., the iron is benefitted by the presence of this higher silicon in the charge.

Soft Iron

So far this Paper has dealt entirely with steel-rail—pig-iron mixtures. The other type of iron used in the author's foundry is that in which no steel rails are used at all; it being a mixture of pig-iron and scrap iron. The analysis which has been followed for years is as follows:—T.C, 3.30-3.50; Si, 2.30-2.50; Mn, 0.50-0.60; S, 0.09-0.11, and P, 0.25-0.45 per cent.

This analysis is a very common one for the general run of small and medium castings. Reference has already been made to the decrease in the total carbon of this particular mixture during the past two or three years. The analysis is so common that it is not necessary to go into any great detail in this connection. It is used in the author's foundry for all the small parts and low pressure pumps where ease of machining is a vital factor, and in some of the larger pumps where the designs lend themselves to such an iron. The sections in which it is used vary from $\frac{3}{16}$ in. up to 1 in., in castings weighing from 4 ozs. up to 500 lbs.

Melting Hot and Pouring Hot

This mixture, when used on pressure work, gives the best results when it is melted hot and poured hot. Every attempt to economise on coke, both as to quality and quantity used, has resulted in lower spout temperatures, more shrinks and draws in the castings and more leakers in the test floors in the machine shops. Invariably, a heat, in which there has been a dull period, is followed by an increase in defectives due to draws or shrinks, at points which are prone to shrink.

Combating Internal Defects

Internal defects and shrinkage may be the biggest sources of trouble in a foundry called upon to cast pressure-work. There are six fundamental principles followed in the author's foundry to combat shrinks, draws and internal sponginess in the castings, which are poured from this soft iron mix. The principles and the order in which they are used are:—

(1) The internal defect commonly called shrinkage, may be caused by gas from the mould or core. Whenever shrinkage is considered, reference is made to (*a*) permeability of the moulding and core sands, and (*b*) venting of the moulds and cores.

Innumerable shrinkage troubles have been eliminated through the use of additional vents in the moulds and cores. One rather simple job returned 25 per cent. loss in leakers. Regardless of the gating practice, the iron mixtures used, etc., the leakers continued. The venting of three small pockets in the cores eliminated the trouble, and the loss dropped below 1 per cent. Impellers for centrifugal pumps developed shrinks and spongy spots on the hubs and wearing rings. A very fine sand was used in the core in order to ensure smooth waterways, for high efficiency. The use of a very coarse open sand and a special core oil which enabled the management to use an oil-sand ratio of 1 to 80 provided a free-venting core which removed the "shrinks." The smooth surface on the rough core was obtained by means of a high-grade plumbago-wash. Thus, reference is made to the venting of the moulds and cores first whenever shrinkage shows up in a type of castings.

(2) If venting does not cure the trouble, experiments are made with the gates. The ingate is placed so that the point at which the shrinkage takes place will get comparatively dull metal, *i.e.*, gate as far from the seat of shrink trouble as possible. Usually the ingate is made as small as will run the casting. Thus, feeding is going on while the casting is being run. Part of the runner which connects the down sprue with the ingate is always placed in the cope, to provide a means of ridding the iron of any slag or loose sand.

(3) If the above gating fails, then the ingates may be placed near the massive part that shrinks and increased in size. Possibly the runner is increased as well as the down sprue. A strainer core is then placed in the pouring basin at the top of the cope to serve both as a choke for slow pouring and to keep the basin full to prevent slag and dirt from being carried into the mould. As soon as the mould is full, the sprue then acts as a feeding head. If the strainer core is set in the joint of the mould, the sprue shuts off quickly, and so does not serve as a feeder. The runner and ingate may be enlarged as stated, to further the feeding effect of the sprue.

(4) If the above methods fail, a riser is used. The riser and the opening from it to the casting are made as large as the casting will permit so that feeding takes place until the casting is set. Quite often the use of a riser with this soft grade of iron makes for a coarse open grained structure where the riser joins the casting.

(5) If this be so, then chills are used, but no riser. The use of chills or denseners is never

TABLE I.—*Physical Data of the Fe-C-Si System.*

Per cent. Si.	Per cent. C.	Temperature at which freezing starts.	Temperature at end of freezing.	Per cent. of solid metal when eutectic temperature is reached.	Per cent. of liquid eutectic.
1.50	2.50	1,315 deg. C. / 2,400 deg. F.	1,126 deg. C. / 2,060 deg. F.	60	40
1.80	3.00	1,248 deg. C. / 2,280 deg. F.	1,126 deg. C. / 2,060 deg. F.	35	65
2.50	3.25	1,201 deg. C. / 2,195 deg. F.	1,126 deg. C. / 2,060 deg. F.	15	85
2.50	3.50	1,162 deg. C. / 2,125 deg. F.	1,126 deg. C. / 2,060 deg. F.	—	100

a complete cure, but considerable relief may be had from them.

(6) If all of the above measures fail on any one job, the management discontinues casting them in soft iron. It then uses a high duty iron, analysing from 1.80 to 2.00 per cent. Si and 3.00 to 3.20 per cent. total carbon, adding 1 per cent. of nickel, in the ladle, for machinability. Usually one can dispense with risers and use common gating practice.

It is a personal belief, in connection with this soft iron mixture, that the condition of the carbon in the charge affects the condition of the carbon in the finished casting. That is, a finely-divided graphite in the pig-iron and the scrap used makes for a finely-divided graphitic carbon in the casting, provided the cupola is operated so as to bring the charges down hot and rapidly. The modern pig now being cast, which weighs only 40 lbs. shows a much finer grain-structure, and a slightly higher combined carbon than the old pig of twice the size, because the small pigs cool much more rapidly. The use of some outside scrap, of such a size and wall section that the graphitic carbon will be finely divided and in not too great a quantity is good practice.

Conclusion

For castings to withstand internal pressures, the most important element in cast iron is carbon. Personal practice indicates that decreasing the total carbon content below the percentages usually encountered in high duty irons, the means by which it is decreased, and the hot-pouring of these lower carbon irons make for a finer-grained structure. This refining of the grain-size provides both pressure-tightness and increased strength.

An attempt was made to ascertain the manner in which the iron mixtures, mentioned in this Paper, freeze. Data were taken from the works of Hanson, Honda, Murakami, Gonterman, Kriz and Poboril in connection with the liquidus surface of the iron-silicon-carbon system. Table I gives these data. The answer to the question of why a casting weighing 2,000 lbs., consisting of sections varying from $\frac{1}{8}$ to $2\frac{1}{2}$ in. in thickness and cast with no feeding heads does not show any signs of internal defects is not apparent to the author in this table. It does show why low carbon irons trap gases given off by the mould and core.

The author takes this opportunity to express his thanks to Prof. G. B. Upton, of Cornell University, for his aid.

130-Ton Steel Castings for Mill Housings

Six steel castings produced recently by the Continental Roll & Steel Foundry Co., East Chicago, Ind., are believed to be the largest ever poured west of Pittsburgh. Weighing about 130 tons each, these castings comprise the housings for a new 84-in. strip mill. Each mould was made in a flask, 14 ft. wide and 36 ft. long, which was located in a shallow pit, with the housing pattern lying horizontally. Actually a slope of $\frac{1}{2}$-in. per lineal foot from the horizontal purposely was created in the flask, the top section of the housing being at the lower level. Composition of the metal poured was approximately as follows:—Carbon, 0.22 to 0.27 per cent.; manganese, 0.65 to 0.85 per cent.; silicon, 0.30 to 0.45 per cent.; sulphur, 0.045 per cent., and phosphorus, 0.03 per cent. Metal was obtained from three open-hearth furnaces and poured almost simultaneously from three ladles. Slightly over 2 min. was required for the metal to reach the risers, with an additional 12 min. employed in feeding the risers. Total amount of metal charged in the open-hearths for the pouring was 289,000 lbs. After $3\frac{1}{4}$ hrs. 20,000 lbs. more metal was introduced into the mould, and about 2 hrs. later 6,000 lbs. additional was poured. The casting was permitted to remain in the mould 10 to 12 days for cooling before removal to the annealing oven. The normalising operation required 16 days.—"Steel."

Recent Metallurgical Developments

Before a meeting of the Institution of Civil Engineers in London recently M. Charles-Eugène Schneider, governing director of Schneider et Cie, Le Creusot, discussed the important part which metallurgy has played in connection with advances in engineering practice. He pointed out that the present year 1936 was the hundredth anniversary of the taking over of Creusot works by his grandfather, who was responsible for their large and rapid development. Since that time those in charge of the works had never ceased to entertain friendly relations with the British iron and steel industry and to exchange ideas and results of experiments and discoveries with British metallurgists.

Proceeding, M. Schneider said that in 1836 the metallurgy of iron was in a process of evolution, and many works still used old methods. France was then the second metallurgical country in Europe, the first place being occupied by England, whose output of pig-iron and wrought iron was equal to that of the rest of the world. Of the 543 furnaces in blast in France, 502 were fired with charcoal and their output was restricted by the output of the forests. The old forges had to be located near forests and on the banks of rapid flowing streams suitable for working the hearth bellows and small mechanical hammers by water wheels. The introduction of the use of coal in the manufacture of pig-iron led to a complete change in methods of working and the location of plants. In 1836 Messrs. Schneider owned four coke blast furnaces and produced 7,000 tons of iron in bars and plate, whilst the total production of steel for making such things as tools and arms in France was about 6,000 tons.

In the beginning those responsible for the introduction of new ideas were limited by the facilities available, but during the last century new processes and new appliances had placed at the disposal of engineers facilities of the highest importance. The electric furnace, introduced in 1900, meant for the refined and special steel industry an advance similar to that afforded by the Bessemer converter in the manufacture of ordinary classes of steel. The era of electricity also radically transformed the rolling mills. Whilst in 1865 the Creusot works needed twenty-six rolling-mill sets to roll 100,000 tons per annum, in a modern steelworks of 1 million tons capacity to-day, five graded sets would suffice for producing all the usual bar sections.

Research Work

Quality improved at the same time as quantity. In 1885 two Creusot scientists, Osmond and Werth, established the proof of the cellular and crystalline structures of steel and alloys with the aid of photography, and the relations existing between the state of the constituents of steel and its mechanical properties, together with the influence of variations of temperature upon the state of the constituents of steel, formed the subject of researches by many other scientists. New methods of metallographic investigation were completed by resorting to oblique illumination, which enabled the identification of certain inclusions otherwise invisible.

M. Schneider referred to the study being carried out in French laboratories of micro-analytical processes with a view to investigating micro-segregation. New testing machines due to M. Chévenard enabled the determination of the mechanical characteristics of a small piece of metal and proved most useful in autogenous welding technique. Corrosion tests, mechanical tests in the hot state, and repeated torsion and bending tests supplied data which were absolutely essential to-day for the engineer. X-ray examination enabled information to be obtained concerning the homogeneity of steel, and was proving most useful for the verification of welds in platework. He mentioned also spectrographic analysis with an X-ray beam to determine with certainty the limits of solid solutions, to study definite compounds and their crystalline system, and to throw light upon the phenomenon of cold working or re-crystallisation. This exploring of the microscopic particles would procure data of the highest interest on special steels, on methods of forging and also on the heat-treatments which were most suitable for their different uses.

Alloy Steels

In connection with alloys, the speaker said that nickel was the best alloy metal to act upon the critical range of quenching, since it increased hardness without making for brittleness and allowed of decreasing the percentage of carbon when an increase in hardness was not desired. The use of chromium, the addition of molybdenum and of titanium, the perfecting of thermal treatment and of pickling, and the smoothing of the surfaces, all combined, had enabled metallurgy to offer to the chemical industry a whole series of steels having notable mechanical properties, which could be worked up, machined and welded and were at the same time capable of resisting for long periods the strongest chemical reagents. Among these steels the best known and most commonly used was one having an austenitic structure containing 18 per cent. of chromium and 8 per cent. of nickel.

The speaker referred also to the work carried out by metallurgists in the study of steel which showed satisfactory resistance at high temperatures both to mechanical stresses and to oxidation, and mentioned that chromium steels containing a certain proportion of nickel, tungsten and vanadium would withstand temperatures of even 2,000 deg. Fah. He mentioned the great increases in the pressures employed in tubular boilers, and the advance in the use of steel in railway carriage bodies, where there was a tendency to replace mild-steel sheets by sheets of nickel-chromium-molybdenum steel, the elastic limit of which was almost double that of the former. Thanks to the improvements made, which were due in part to the manufacturer of steel, 1,000-ton trains could now travel at a speed of over 80 miles an hour more safely than the 100-ton trains in 1840 ran at 25 miles an hour. The motor car and the aeroplane owed many of their recent advances to the results obtained by metallurgists. Recent military aviation engines weighed hardly 1.1 lbs. per h.p. and there had been a corresponding decrease in the weight of the framework due to the manufacture of a whole series of light alloys having a specific gravity of 2 to 3 and a strength comparable to that of mild steel.

As an example of the improvements reached, M. Schneider quoted the fact that the length of round wire which could bear its own weight had increased from 2.5 miles for puddled iron wire and 3.3 miles for mild steel wire to about 15 miles for wire of special nickel-chromium-tungsten steel. The use of special steels had also led to an increase in span in cantilever and suspension bridges, to making possible still deeper winding depths in collieries, and to improvements in the design of internal-combustion engines and turbines. In connection with turbine shafts, he pointed out that one of the special conditions that had to be observed in their manufacture was to prevent any possibility of their undergoing deformation at their actual working temperatures. This meant that no residual stress should remain in them following thermal treatment. In France Messrs. Mesnager and Jouguet discovered methods to arrive at the residual stress in question, but these were costly and took time. His firm had, however, perfected an approximate method called the "Prism Method" which consisted of measuring the deformation of a test prism in the course of machining.

The Fatigue of Cast Iron

By J. W. DONALDSON, D.Sc.

Since the work of Wöhler was published over sixty years ago, a considerable number of investigations has been carried out on the endurance limit or fatigue strength of metals and alloys. In those investigations, materials have been subjected to repeated loading tests involving direct, bending, and torsional stresses with a view to ascertaining the safe range of applied stress to which such materials can be subjected, and such stresses have been found to be an important factor in the life of such materials. Particular attention has also been paid to the influence of surface finish on the endurance limit of metals, and to the importance of avoiding sudden changes in section in parts subjected to fatigue stresses.

The larger proportion of the work has been on the fatigue strength of steel and non-ferrous alloys, and the amount of information available regarding the fatigue of cast iron is very limited. The lack of data regarding this property of cast iron probably results from the fact that cast iron is of such a complex nature that it is difficult to test it in the same systematic manner as steel and non-ferrous alloys are tested, and partly due to cast iron being largely used under static conditions for such parts as bedplates, frames, columns, pedestals, etc. The use of cast iron, however, for rotating and other moving parts of machinery, involving rapid and continuous reversals of stress, has developed greatly of recent years, and has necessitated more attention being paid to the determination of the endurance properties of this alloy. Investigations on the fatigue properties of cast iron have been principally carried out in the United States and in Germany and to a lesser extent in this country, and the object of the present article is to summarise and review those investigations and to consider the data available regarding a property of cast iron which is of importance to all designers and users of machinery.

Early Experiments

In 1850 a series of experiments was made by James and Galton to determine the effect of repeated changes of load on iron, with a view to its application to railway structures, and it was concluded that cast iron could be fractured under repetition of a load of a magnitude which would not produce fracture on a single application, and that the static strength remained unaltered. These tests were probably the first to be made on the endurance strength of cast iron. In 1911 the first systematic tests were made by Eden, Rose, and Cunningham[1] in an investigation on the endurance of metals, in which a very large number of metals, principally steels and wrought irons, were tested on a rotating beam machine, so that the test specimens were subjected to a uniform bending moment while revolving on their own axes. Five cast irons were tested, and, with one exception, either broke within two minutes of the application of the load, or remained unbroken. Two of the irons with loads of 9.8 and 8.9 tons per sq. in. remained unbroken after 622,000 and 830,000 revolutions respectively.

Bulleid's Tests

At the 1926 meeting of the British Association the results of a series of tests on the fatigue strength of cast iron were presented by Bulleid.[2] The tests described were carried out in a special type of Wöhler reverse bending machines with automatic recording apparatus, the specimen being rotated 1,000 times per min. Thirty-six bars of an iron, containing approximately 2.4 per cent. silicon, 1.4 per cent. phosphorus, 0.65 per cent. manganese, were tested in a variety of ways, and at the higher stresses gave rather irregular results, fracture occurring almost at once for a reversal of stress of ± 14.5 tons per sq. in., while at a lower stress, a definite limiting stress for 10 million reversals was obtained with ± 9.7 tons per sq. in. It was concluded from these tests that the phenomenon of fatigue in cast iron, when carried out by the simple reversal of a bending stress, was not essentially different from that of other metals such as steel.

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Further tests on the same machine were carried out by Bulleid and Almond[3] on two cast irons. The first iron, described as an iron suitable for light castings, had an ultimate tensile strength of 11.9 tons per sq. in., a transverse strength of 18.7 tons per sq. in. and a fatigue limit after 10 million reversals of ± 6.4 tons per sq. in., while the corresponding values for the second iron described as a typical cylinder iron were 19.9, 11.4, and ± 3.2 tons per sq. in. respectively. From these values it was concluded that the ratio of fatigue stress to transverse stress varied greatly for different irons and might be very low, and that the low value obtained for the cylinder iron was accounted for by the presence of large graphite flakes. In the discussion, which followed the publication of these results, the dissimilarity of the casting conditions of the two irons were commented on, and the poor results obtained for the cylinder iron were attributed to the fact that the test specimens were turned out of the centre of a thick slab, where the cooling would be slowest and the graphite flakes largest, and that if the position of the test specimens and the size of the castings from which they were cut had been more uniform, the cylinder iron would have shown a fatigue value more in accordance with the higher static values obtained for it.

TABLE I.—*The Composition of Cast Irons (Moore, Lyon and Inglis).*

No.	91	92	93	94
T.C ..	3.56	3.44	3.30	3.31
C.C ..	0.84	0.68	0.52	—
Gr.C ..	2.72	2.76	2.78	—
Si	1.42	1.10	1.10	1.14
Mn	0.32	0.62	0.60	0.58
P	0.75	0.51	0.46	0.38
S	0.065	0.093	0.096	0.102

American Experience

The first systematic fatigue tests on cast iron were carried out by Moore, Lyon, and Inglis[4] at the University of Illinois. Four cast irons were tested, drawn from the following sources: (*a*) 6-in. centrifugal sand-cast pipe, (*b*) and (*c*) 18-in. by 12-in. hollow cylinders cast in green sand with dry sand cores, and (*d*) the inner wall of a double-walled cylinder weighing 25 tons. The composition of these irons was somewhat similar and is given in Table I, and the microstructures of the first three were essentially pearlitic, while the fourth contained its carbon almost entirely in the form of graphite. The tests to which these irons were subjected included tension, compression, Charpy impact, Brinell hardness, and fatigue tests, and a summary of these tests, together with the ratios of the fatigue tests to the static tests, is given in Table II. The fatigue tests were made on a rotating beam Wöhler machine of the Farmer type, and the safe range of stress was determined in each case at less than 10 million reversals. The fatigue tests show an endurance limit of approximately ± 5.4, ± 4.7, ± 4.4, and ± 3.3 for the four irons, and the ratio of endurance limit to tensile strength is lower than that usually found for steel and cast or wrought non-ferrous alloys, which are usually found to range from 0.4 to 0.5. Only the iron cast centrifugally has a ratio over 0.4.

Several series of special tests were also carried out on one or more of these irons. Irons Nos. 93 and 94 were subjected to a series of understressing tests, when the fatigue value was found to be raised by from 16 to 43 per cent. The latter value which was obtained with iron No. 94 was much superior to the 30 per cent. maximum obtained with steel. A series of experiments on the effects of radial holes and circumferential grooves in lowering the endurance limit did not show the expected order of reduction in the fatigue strength, which would be expected from a material of the nature of cast iron, a much larger percentage of reduction of endurance limit by a similar groove being found in the case of steel and annealed copper.

Static tensile tests, Brinell hardness determinations, and fatigue tests were also made on cast iron No. 92 at various temperatures up to 760 deg. C. Prolonged loading tests, intermediate between the ordinary rapid loading tests and creep tests, showed the tensile strength to diminish from 13.4 tons per sq. in. at 20 deg. C. to 5.3 tons per sq. in. at 540 deg. C. and to 1.5 tons per sq. in. at 760 deg. C. The fatigue strengths diminished in a more uniform manner, being ± 5.3, ± 4.5, and ± 2.9 tons per sq. in. at similar temperatures, and exceeding the static tensile tests for temperatures exceeding 590 deg. C., a fact which was previously established for a nickel-copper alloy tested by Tapsell and Bradley.[5]

TABLE II.—*Static and Fatigue Tests (Moore, Lyon, and Inglis).*

No.	Tensile strength. Tons per sq. in. *a*	Compressive strength. Tons per sq. in. *b*	Brinell hardness. *c*	Endurance limit. Tons per sq. in. *d*	Endurance ratios. $\frac{d}{a}$	$\frac{d}{b}$	$\frac{d^*}{c}$
91	11.7	42.9	162	± 5.4	0.46	0.125	74
92	13.9	50.0	148	± 4.7	0.33	0.095	71
93	12.1	39.7	136	± 4.4	0.36	0.106	70.9
94	9.3	37.0	89	± 3.3	0.35	0.087	79.5
Mean	—	—	—	—	0.37	0.102	75.6

* Endurance limit in lbs. per sq. in. for the ratio $\frac{d}{c}$.

A few tests of specimens of cast iron No. 92 were made to determine the endurance limit for cycles of stress ranging from zero to a maximum. One series of tests was made by superimposing a steady tensile stress on a specimen subjected to cycles of reversed flexure, and a second was made on specimens subjected to cycles

of axial stress varying from zero to a maximum in compression. The values for the endurance limits obtained are given in Table III, where the term "range ratio" is used to denote the ratio of minimum (numerical) stress during a cycle to the maximum. Consideration of these results shows that the ratio of endurance limit for cycles of stress varying from zero to a maximum in flexure (range ratio = 0) is 1.48 times the endurance limit for cycles of completely reversed flexure (range ratio = − 1), a result which is not widely different from that found in tests of steel. In Fig. 1 the general results are given, following the general plan of the well known Goodman diagram for range of stress, but extending the diagram into the field of cycles

TABLE III.—*Endurance Tests (Moore, Lyon, and Inglis).*

Property.	Symbol.	Value.
Endurance limit under reversed flexure (range ratio = − 1). Tons per sq. in.	S–1	± 4.7
Endurance limit under stress range from zero to maximum tension (range ratio = 0). Tons per sq. in.	S′o	± 7.0
Endurance limit under stress range from zero to maximum compression (range ratio = 0). Tons per sq. in.	S″o	± 29.0
Tensile strength. Tons per sq. in.	S′n	14.1
Compressive strength. Tons per sq. in.	S″n	50.0
Endurance ratio for tension ..	$\frac{S'o}{S'n}$	0.49
Endurance ratio for compression	$\frac{S''o}{S''n}$	0.58
Endurance ratio for alternating stress	$\frac{S–1}{S'n}$	0.33
Endurance ratio for alternating stress	$\frac{S'o}{S–1}$	1.48

of compressive stress. The part of the diagram in broken lines is extrapolated beyond the test data.

Tests on High-Duty Cast Iron

A second series of systematic fatigue tests was carried out at the University of Wisconsin by Kommers,* involving tests on ten different cast irons, covering the range from low strength to high strength materials, and cast in the form of the A.S.T.M. Standard Arbitration Bar. The tests included tensile tests on two different sizes of specimens, compression tests, tranverse tests, Rockwell and Brinell hardness determinations and fatigue tests. In the fatigue test the specimens were subjected to completely reversed bending stresses in tension and compression, at a rate of about 1,750 revs. per min., and in general 20 million cycles were used as the maximum run. In Table IV are given the ratios of the endurance limit to the various static results obtained.

Consideration of these results shows the ratios of endurance limit to tensile strength to compressive strength, to Brinell hardness, and to modulus of rupture to be most consistent. The ratios of endurance limit to tensile strength, compressive strength and Brinell hardness are somewhat higher than those obtained by Moore, Lyon, and Inglis as given in Table II, and may possibly be due to the fact that special precautions were taken in the fatigue tests to prevent vibrations, by mounting the frame of the fatigue machine on four coiled springs, and also by hanging the applied load from another coiled spring, and thereby obtaining a higher endurance limit.

The irons in series H and K, which were of somewhat similar composition, except for the addition of 1.15 per cent. of nickel to the former, had tensile strengths of 22.8 and 19.0 tons per sq. in. respectively, and may be regarded as high-strength cast irons. The endurance limits for these two irons ± 9.8 and ± 10.8 tons per sq. in. were the highest values obtained for the various cast irons. The irons in series F and G were of the same composition except that series F contained 0.63 per cent. of nickel and 0.22 per cent. of chromium. The addition of these alloys to the former had a slight strengthening effect, raising the tensile strength from 15.9 to 16.5 tons per sq. in. The corresponding fatigue values were ± 8.5 and ± 8.7 tons per sq. in., and the ratios endurance limit to tensile strength 0.53 and 0.54. The higher strength in the cast irons of series H and K over the irons of series F and G result from their total carbon contents, which average 2.92 and 3.40 per cent. respectively. No advantage appears to be gained in the ratio of endurance limit to tensile strength by alloy additions, but it must be stated that the tests were not carried out with the view of bringing out the advantages of alloy additions in cast iron.

Extracts from German Work

In an investigation dealing with the elasticity and fatigue strength of cast iron Thum and Ude† determined the fatigue strengths of 14 irons. These irons were of varying compositions containing 2.94 to 3.77 per cent. carbon, 0.91 to 2.60 per cent. silicon, 0.21 to 1.39 per cent. phosphorus, and 0.50 to 1.18 per cent. manganese, and their microstructures ranged from pearlite and fine graphite to ferrite and coarse graphite. The tests carried out included both static and fatigue tests, the latter being determined on ground test bars, clamped at both ends in a Schneck continuous bending test machine, where they were subjected to vibrational bending stresses. The highest fatigue values were obtained in the irons having a pearlitic ground mass, and finely divided graphite, and approximated to ± 7.6 tons per sq. in., while the lowest values approximating to ± 3.8 tons per sq. in. were obtained in the irons containing a large proportion of ferrite and coarse graphite. Irons which showed transition zones from pearlite to ferrite or were on the border of becoming white irons, had medium fatigue values. The ratio fatigue strength to tensile strength varied from 0.35 to 0.45, and was not confined to a particular type of iron, although in general the ratio was higher with the higher tensile irons.

Effect of Surface Finish

With a view to ascertaining the effect of surface finish and notch-sensitivity on the endurance strength, special tests were carried out on four of the cast irons, two having high fatigue values, and two having medium or low fatigue values. The tests were made on polished test bars, rough planed bars, bars ground with emery, bars with a 0.1 mm. tapered notch, and bars with a 0.1 mm. flat notch. The method of surface treatment was found to have practically no effect on the fatigue strength, but with regard to notches, the high-quality cast irons showed a greater decrease in strength than did the medium or low types, the decrease in the former being about 12.5 per cent., while the latter remained virtually unchanged. The reason for the falling off in endurance strength in the high-quality irons was considered to be due to the graphite, in that the coarse graphite flakes of the lower types of iron might be regarded as a series of extremely fine notches, and that an additional artificial notch produces less change than would be produced by a similar notch in an iron where the graphite is in a finely divided state. High-quality irons have therefore to be treated with a greater degree of care in fabricating and machining, so that notches and sudden changes of section are avoided, if the endurance strength is to be maintained.

Graphite and Notch Effect

Another investigation was carried out in Germany on the fatigue strength of cast iron in terms of its structure and surface properties by Pfannenschmidt,‡ who determined the endurance limit of a series of ordinary and alloy cast irons. Fatigue tests were made on a fatigue testing machine of the Wöhler type, and the specimens

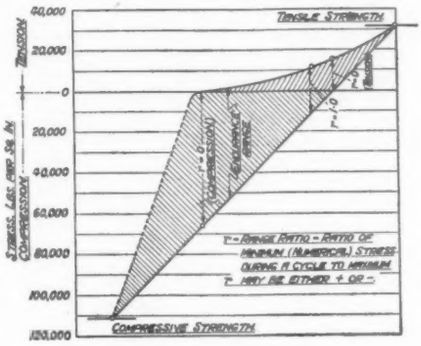
TENSILE STRENGTH
TENSION
COMPRESSION
COMPRESSIVE STRENGTH
R = RANGE RATIO = RATIO OF MINIMUM (NUMERICAL) STRESS DURING A CYCLE TO MAXIMUM
R MAY BE EITHER + OR −

FIG. 1.—VARYING ENDURANCE LIMITS OF CAST IRON WITH VARYING RANGE OF STRESS (KOMMERS).

were subjected to a limit of stress reversals not exceeding 5 million. The six unalloyed irons tested had tensile strengths varying from 12.6 to 18.9 tons per sq. in., according to their structure and method of manufacture, with corresponding fatigue values of from ± 5.7 to ± 9.5 tons per sq. in., and a ratio of fatigue strength to tensile strength of 0.45 to 0.53, depending on the quality of the iron. In this series of irons the endurance limit was also improved by refining the surface of the specimen by roll-polishing, values of ± 6.10 and ± 10.8 tons per sq. in. being obtained for the lowest and highest tensile irons with a consequent increase in the fatigue to tensile ratio of from 0.48 to 0.57. The increase in strength was highest the finer the distribution of the graphite, due to a less internal notch effect.

TABLE IV.—*Ratios of Endurance Limits to Static Tests (Kommers).*

Iron.	Ratio endur. limit to tensile strength.	Ratio endur. limit to compress strength.	Ratio* endur. limit to Rockwell hardness.	Ratio* endur. limit to Brinell hardness.	Ratio endur. limit to mod. of rupt.	Ratio endur. limit to energy rupt.
A	0.53	0.174	216	94.0	0.26	512
B	0.48	0.138	197	91.8	0.29	900
C	0.50	0.128	168	77.6	0.26	825
D	0.38	0.098	135	62.3	0.20	553
E	0.42	0.115	143	72.7	0.22	573
F	0.53	0.148	204	93.2	0.29	783
G	0.54	0.146	206	96.8	0.28	713
H	0.43	0.141	219	92.2	0.25	500
J	0.51	0.139	136	68.8	0.22	715
K	0.57	0.156	251	101.8	0.32	746
Mean	0.49	0.138	187	85.1	0.26	682

* Endurance limit in lbs. per sq. in. for Rockwell and Brinell hardness ratios.

Alloyed Cast Iron

The eight alloy cast irons investigated contained additions of nickel, chromium, and molybdenum, either together or singly. The composition of these, together with their tensile

and fatigue strengths, and the ratio of the two strengths are given in Table V. Considerations of the results obtained show those irons to have tensile strengths varying from 11.4 to 20.2 tons per sq. in., with endurance limits which give fatigue tensile ratios of from 0.40 to 0.80 and an average of 0.60, and two lowest values being obtained with the brittle chromium irons having a high proportion of combined carbon. The influence of roll polishing was only determined on the iron containing 1.7 per cent. nickel and 0.5 per cent. chromium, when the fatigue value was found to increase from ± 10.8 to ± 11.4 tons per sq. in. and to give a ratio of 0.57. All the tests whether on alloyed or unalloyed irons were carried out on specimens taken from castings produced in the ordinary process of manufacture.

TABLE V.—*Endurance Tests on Alloy Cast Irons (Pfannenschmidt).*

No.	Composition.									Tensile strength. Tons per sq. in. *a.*	Brinell hardness.	Endur. limit. Tons per sq. in. *b.*	Endur. ratio. $\frac{b}{a}$.
	C.	G.C.	Si.	Mn.	P.	S.	Ni.	Cr.	Mo.				
627..	2.32	1.40	1.07	0.49	0.30	0.06	1.70	0.5	—	20.2	255	± 10.8	0.535
Cr ..	3.24	2.28	1.34	1.08	0.25	0.06	—	0.5	—	16.1	215	± 6.7	0.400
C_2 ..	3.17	1.39	1.23	0.82	0.35	0.04	—	0.86	—	16.05	241	± 7.9	0.495
M_1 ..	2.80	1.92	2.69	0.77	0.39	0.06	—	—	0.55	12.05	252	± 9.8	0.815
MNC	3.19	—	1.64	—	0.15	0.035	0.71	0.49	0.46	12.70	255	± 8.6	0.680
M ..	3.28	2.67	2.06	0.62	0.15	0.059	—	—	0.33	11.45	168	± 7.3	0.640
M_2 ..	2.86	1.92	1.28	0.80	0.48	0.08	—	—	0.74	18.35	229	± 9.8	0.540
MCr	2.85	1.92	2.17	0.73	0.44	0.047	—	0.50	0.63	18.05	—	± 10.8	0.60

Tests on four different engineering irons, one of which was tested in the cast and also in the heat-treated condition, were carried out by Moore and Picco.[9] The tests included static tensile and compression tests, Brinell hardness determinations, fatigue tests under cycles of completely reversed flexure, fatigue tests in flexure varying from zero to a maximum stress in one direction, fatigue tests under cycles of completely reversed torsion, and fatigue tests in torsion varying from zero to a maximum stress in one direction. The results obtained indicated that in general the fatigue stress is approximately proportional to the static tensile stress, an endurance ratio varying from 0.33 to 0.44 being obtained, the former value being that of the heat-treated iron, and the latter value being that of the same iron as-cast.

Influence of Speed on Endurance Limit

Krouse[10] in experimenting with a high speed fatigue testing machine driven by an air turbine and operating over a range of speed from 5,000 to 30,000 revs. per min. and designed for a shorter method of determining endurance limit, tested a grey and an alloy cast iron. With the plain cast iron there was little variation in endurance limit, with considerable variation of speed within the limits 5,000 to 30,000 revs. per min., but the alloy cast iron showed an increase of about 10 per cent. in endurance limit at 30,000 revs. as compared with 10,000 revs. Tests carried out on specimens having a V-notch 0.01 in. deep showed an increased endurance limit for the grey iron and a decreased endurance limit for the alloyed cast iron.

Low-Temperature Tests

Another series of high speed fatigue tests were carried out by Boone and Wishart[11] on several ferrous and non-ferrous metals. These tests, which were carried out at low temperatures ranging from 80 deg. to − 40 deg. F., included two cast irons. These cast irons were a grey cast iron containing 3.25 per cent. C, 1.10 per cent. Si, 0.60 per cent. Mn, 0.46 per cent. P, 0.096 per cent. S, and a Meehanite cast iron containing 3.07 per cent. C, 1.26 per cent. Si, 0.90 per cent. Mn, 0.15 per cent P, and 0.08 per cent. S. The tests were carried out in a cold room on a high-speed cantilever fatigue-testing machine developing a speed of 12,000 revs. per min., the fatigue limit being based on 10 million cycles. Tests were made at four temperatures on unnotched and notched specimens, the notches in the latter being 0.01 in. radius. The results obtained, together with the stress concentration factor as determined by the ratio of endurance limit of the unnotched to the notched specimen, are given in Table VI. Consideration of these results shows the two irons to have normal fatigue values at ordinary temperatures, and that those values increase as the temperature decreases. The notched bars of the grey cast iron show an increase in their fatigue strength over the unnotched bars, whereas in the high-duty iron the fatigue values of the notched specimens are less, results which are in agreement with those of Krouse[10] for unalloyed and alloyed cast irons. The stress concentration factors of the two irons shows no consistent change with decreasing temperature.

N.P.L. Experiment

In investigations relating to the behaviour of metals under cyclical stressing or fatigue, most attention has been devoted to endurance tests employing simple stress systems, such as direct, flexural or torsional stresses, and very little information is available regarding the effects of combined fatigue stresses. With the object of obtaining such data a special, high speed, fatigue testing machine has been designed at the Engineering Department of the National Physical Laboratory, in order to study the behaviour of metals under combined alternating plane, flexural and torsional stresses; and a programme has been drawn up for the testing of fourteen steels, and three types of cast iron, the latter to include a comparatively brittle and a comparatively ductile type, together with a high-quality engineering iron, which in respect of ductility is intermediate between the former two. In the first report published on this research by Gough and Pollard,[12] the new testing machine is described, and a comprehensive study of a mild steel, a nickel-chromium steel, and Silal cast iron under plane bending and torsional stress and under five combinations of these stresses in addition to a series of static and other supplementary tests are presented. The Silal cast iron contains 2.09 per cent. C, 6.39 per cent. Si, 1.13 per cent. Mn, 0.047 per cent. P, 0.031 per cent. S, 0.08 per cent. Al, and has a tensile strength of 14.9 tons per sq. in., a Brinell hardness of 305, a fatigue limit on the Wöhler rotating bar testing machine of ± 14.9 tons per sq. in. with an endurance ratio of 1.0, and a torsional fatigue limit on the Stromeyer alternating torsional machine of ± 12.9 tons per sq. in., with an endurance ratio of 0.87. A comparison of these fatigue limits with the fatigue limits determined on the combined fatigue stress machine are given in Table VII, and appear to indicate that there is a slight but real increase in the fatigue limit under combined stresses over the fatigue limits obtained with the Wöhler and Stromeyer machines. Previous experiments have shown that the fatigue or endurance limits of ordinary cast irons give comparatively high endurance ratios, but this investigation has shown for the first time a ratio of unity, the previous best being obtained by Pfannenschmidt[8] with an alloy cast iron as 0.815. Such a high endurance ratio results from the high endurance limit obtained and from the fact that the tensile strength is low, and appears to indicate that brittle cast iron of this type behaves better under fatigue stress than under static stress.

TABLE VI.—*Endurance Limits at Various Temperatures (Boone and Wishart).*

Temp. Deg. F.	Grey cast iron. Endur. limit. Tons per sq. in.		Meehanite iron. Endur. limit. Tons per sq. in.	
	Unnotched.	Notched.	Unnotched.	Notched.
+ 80 ..	± 4.0	± 4.5	± 9.4	± 8.9
+ 10 ..	± 4.0	± 4.5	—	—
− 20 ..	± 4.3	± 4.3	± 10.3	± 9.9
− 40 ..	± 5.1	± 6.0	—	—

Conclusions

The various investigations and researches carried out on the fatigue of cast iron have shown that this material has a relatively higher endurance limit or fatigue strength in relation to its tensile strength, when compared with other metals and alloys, an endurance ratio of 0.45 to 0.60 being obtained. The fatigue strength is not increased in high-duty irons or by alloy additions, except in so far as the ultimate tensile stress is increased, an equally high endurance ratio being obtained with medium and low grade irons. Brittle cast irons both alloyed and unalloyed have been found to have endurance ratio above the average values, and in one iron the ratio has approached to unity. The ratio of fatigue strength to compressive strength varies between 0.13 and 0.15, and the ratio of fatigue strength to modulus of rupture approximates to 0.26.

The effect of surface finish on the endurance limit of cast iron is small, only a very slight increase, if any, being found in the fatigue strength with ground or polished test bars. The effect of grooving or notching in decreasing the fatigue strength of cast iron is very much less than that obtained for most other materials, and high-duty cast irons show the effect of notching to a much greater extent than do medium or low quality irons, due to their finer distribution of graphite. Cast iron also retains its fatigue strength at elevated temperature better than its ultimate breaking strength, and at temperatures over 600 deg. C., the fatigue strength has been found to exceed the static tensile strength. Understressing cast iron for a considerable period increases the endurance limit to a greater extent than similar understressing on steel.

TABLE VII.—*Comparison of Fatigue Limits (Gough and Pollard).*

Material.	Tensile strength. Tons per sq. in. *a*	Fatigue limit. Tons per sq. in. Cycles of reversed flexural stress. Combined stress machine (plane bending). *b*	Wöhler machine (rotating bar). *c*	Cycles of reversed shear stress. Combined stress machine. *d*	Stromeyer machine. *e*	Ratios. $\frac{b}{c}$	$\frac{d}{e}$	$\frac{b}{a}$	$\frac{c}{a}$	$\frac{d}{a}$	$\frac{e}{a}$
Silal cast iron	14.9	± 14.8 to ± 15.6	± 14.9	± 13.5 to ± 14.2	± 12.9	0.99 to 1.05	1.04 to 1.10	0.99 to 1.05	1.00	0.91 to 0.95	0.87

[8] Pfannenschmidt, *Stahl und Eisen*, 1933, 53, 1.

[9] Moore and Picco, *Trans. Amer. Soc. Steel Treating*, 1931, 19, 1.

[10] Krouse, *Trans. Amer. Soc. Steel Treating*, 1931, 19, 1.

[11] Boone and Wishart, *Trans. Amer. Soc. Steel Treating*, 1931, 19, 1.

[12] Gough and Pollard, *Proc. Inst. Mech. Engrs.*, 1935, 131, 3.

Cast Iron for Vitreous Enamelling*

By H. T. ANGUS, Ph.D.

Probably the most potent cause of enamelling defects is the evolution of gas at some stage during the fusion, causing blistering and pinholing in the finished enamel. It is generally accepted that the gases concerned are CO and CO_2. There has been, however, very considerable difference of opinion as to the source of these gases.

It has been pointed out, first by Krynitsky and Harrison, that one of the fundamental factors controlling the blistering of iron was the period during which the gas was evolved; in other words, if gas were evolved during the early stages of fusion no material harm would result, as the enamel would have time to flow back over the craters and reform a smooth surface. If, however, the evolution of gas took place at a late stage in fusion, defects might well arise, owing to the enamel being too viscous and having insufficient time to cover the defects. Poste confirmed this in 1933, and has shown that in certain cases blistering irons actually give off less total gas during the rise to fusion temperature than irons which were regarded as non-blistering. Blistering irons, however, produce gas at a later stage of the fusion process than non-blistering irons.

Various contributory causes of blistering have been put forward, namely:—(1) Absorbed gases; (2) porosity in the metal; (3) dirt inclusions; (4) micro-chill, and (5) heat capacity.

Absorbed Gases

If absorbed gases are to be regarded as the most serious source of blistering, it would be expected that blistering would be most prevalent in thin sections rather than thick sections, since the thin sections, cooling more rapidly in the mould, will have less time to release their content of absorbed gases than the thicker sections. On the other hand it would be expected that a full annealing at a temperature above the enamel fusing point would be sufficient to release any absorbed gas and would so prevent further trouble in the enamelling process. As is well known, however, actual practice shows that blistering is always more severe on heavy sections than on thin sections, and also that full annealing does not always eliminate blistering troubles. Tests on the variation of casting temperature confirm this view, there being a tendency to produce slightly more defects with very low temperature pouring (1290 deg. C.) than with high temperature pouring (1450 deg. C.).

Porosity in the Metal

Porous iron is well known to be a contributory factor in the production of defective castings. It is sometimes necessary that a porous section of metal must, of necessity, contain more absorbed gas than a sound part of the same casting. Actually, however, it should contain less absorbed gas, since it is usual for porosity to occur in heavier sections which have had a long period of cooling, and at the same time, gas that has produced the pores in the casting should obviously reduce the total quantity left behind in the metal. It has been suggested that a porous section acts like a sponge and that during heating the pressure in the cavities is increased, and blistering is caused by the actual evolution of gas from the cavities during the heating up period. Usually, however, blistering difficulties take place in the later stages of fusing, or during the cooling down period when the gas should be contracting, and the pressure in the cavities should be falling. Attempts have been made to produce actual blistering, by means of artificial porosity, holes having been drilled very close to the surface of the metal, and plugged, leaving a large sealed cavity which is under the enamelling surface. In no case, however, has this led to the production of blisters when the surface was subsequently enamelled. A third and more likely explanation of the effect of porosity is that the metal may be oxidised on the surface, and also that the pores themselves may serve as a source of additional oxygen.

Dirt Inclusions

Dirt inclusions are known to be a contributory factor. Nevertheless, specific attempts to obtain blistering defects by the addition of (1) spent moulding sand, (2) steel shot dust, and (3) iron oxide (Fe_2O_3) have all failed to produce blistering defects. Small pockets of spent moulding sand have been found to produce spalling and spitting of the fused enamel, but in personal experience have not definitely produced blistering.

Micro-Chill

The theory of micro-chill, first elaborated by Krynitsky and Harrison, suggests that blistering is caused by a very thin skin of chilled metal on the surface of the iron. They state that micro-chill must not be confused with ordinary chill, and it is implied that it can occur in ordinary soft grey iron and is less affected by such graphitising additions as silicon than ordinary chilling. The effect of micro-chilling is to form cementite, which, under the influence of heat breaks down to a submicroscopic graphite nearly approaching temper carbon, and this being more readily oxidised than ordinary graphite or cementite causes a readier evolution of CO and CO_2, producing more or less damage, according to the stage of the enamelling process at which it occurs. The oxygen is stated to be atmospheric in origin. They point out that gas evolution is not bad in itself, unless it occurs at the wrong fusion period. The state of precipitated carbon depends, to some extent, upon the rate of heating; a free, quick firing, by allowing less time for full graphitisation, produces a more reactive carbon, which will tend to produce gas more readily than if it had been produced by a longer period heating. Variations in moisture content of moulding sand are said not to influence the production of micro-chill, and also they state that normal graphite in the iron does not affect enamelling.

The above investigators also state that sulphur does not oxidise preferentially to iron, and is an unlikely source of blistering, but that the addition of manganese (presumably in excess of that required to deal with existing sulphur) had a distinct tendency to cause blistering. It is safe to state that gas evolved before fusion is unlikely to be the direct cause of blistering, as it will escape through the unfused enamel. Their statement that the production of CO and CO_2 is due to atmospheric oxidation requires some qualification. Assuming blistering gases to be produced entirely by atmospheric oxygen, there will be little tendency to give off gas at temperatures below about 680 deg. C.

The critical temperature for the iron oxide/carbon equilibrium is about 680 deg. C., *i.e.*, below that temperature oxidation of iron will occur at the same time as of carbon, and iron oxide and carbon may exist together in a suitable atmosphere of CO and CO_2. Above this temperature carbon oxidises in preference to iron. and where carbon and iron oxide exist together in a limited supply of oxygen, the carbon will burn out completely, and in the event of insufficient free oxygen being available it will reduce the iron oxide. The equilibrium composition of the system $CO/CO_2/Fe/FeO$ is about 58 per cent. CO and 42 per cent. CO_2 at this temperature, involving a volume increase of about 1.3. The absorption of oxygen to form oxide will cause a decrease in volume which will approximately balance out, so that it is almost certain that, so far from iron evolving appreciable quantities of gas due to atmospheric oxidation during fusing, it may even absorb, and is at least as likely to leave the total volume emitted the same as that absorbed. This being the case, the evolution of large quantities of gas by direct oxidation from the air is not likely to occur until a temperature in excess of 680 deg. C. is obtained, at which temperature the enamel fusion has gone some distance, and so further access of oxygen to the iron is shut off, and any oxidation of carbon which takes place subsequently must depend for oxygen upon that shut up in the enamel, and upon iron oxide which has been formed in the pre-fusion period.

The chief evidence for micro-chill appears to be circumstantial only. Microscopic examination does not appear to uphold the presence of any special form of cementite in the surface layers.

Heat Capacity

A series of tests were carried out with a webbed angle section in an endeavour to ascertain the effect of heat capacity upon blistering:—(1) samples cast with web in position; (2) samples cast without web, and (3) samples cast with web in position, but the web subsequently cut away.

Blistering took place on the first samples (1) over the web. No blistering took place with the other sets of samples (2) and (3). This series of tests would appear to eliminate casting defects, burnt-on sand and cast-iron structure variations, and appears to leave only the heat capacity, due to the web, which affected the rate of heating up and cooling down of the enamel in this portion. This conclusion, however, is not borne out by subsequent tests in which blistering on the heavy bosses of a casting was eliminated by using chills in the mould. In this case it would appear that the heating capacity of the heavy boss had nothing to do with the defect, and that the cause of the defective enamel was porosity or graphite formation in the metal.

(*Concluded on page* 14.)

* A Paper presented to the recent Scottish Conference of the Institute of Vitreous Enamellers.

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In the foregoing the author has largely eliminated the possibility of gases absorbed during melting, the effect of gas directly trapped in pores, the effect of dirt inclusions, as such, and the direct effect of heat capacity. Air entrapped in the biscuit enamel, and atmospheric air during the process of fusion have been shown to be inadequate sources of the oxygen required to oxidise graphite or carbide and produce blistering gases, although some surface oxidation of iron may take place, due to air in the pores of the unfused coating.

It is not always realised that removal of carbon during annealing can take place without the formation of a surface skin of iron oxide, and it can be stated that in a limited supply of air a surface layer of oxide cannot form above red heat until most of the immediate surface carbon has been removed. The formation of an oxide coating follows the course of:—(1) Production first of temper colour and very fine uniform skin of oxide, while passing through temperatures below red heat. (2) Solution of oxide coat in the surface layer, and oxidation of carbon, and if the amount of available oxygen be small, oxidation of the carbon may completely reduce any oxide on or in the surface of the iron and leave it entirely free from oxide. (3) Saturation of the surface layer of iron with oxide and growth of nuclei of oxide to form a continuous oxide layer.

Where there is an unlimited supply of oxidising gases (1) will proceed directly and oxidation of carbon will proceed at the same time as oxidation of iron.

Removal of carbon from the surface may take place during annealing without the formation of scale. As mentioned earlier, carbon, iron and iron oxide can exist together below 650 deg. C., but above 685 deg. C. carbon will always be oxidised, in preference to the iron, and since the evolution of blistering gases in general takes place during the later stages of fusion it is almost certain that the main source of oxygen is in iron oxide which has formed on the surface or below the surface in porous cavities, or is actually dissolved in the metal itself.

Blistering, therefore, appears to depend upon a combination of factors:—(1) The ability of an iron surface to absorb oxygen and oxide. This absorption in the casting may take place during cooling of the mould, during annealing prior to shot blasting, or during the early stages of fusion, and is controlled by (2) graphite formation and porosity of surface or subsurface. Fine graphite is usually better than coarse graphite, for, although the total surface of carbon exposed on the surface of the flakes is greater, fine graphite is usually the index of a dense, non-porous casting, which is therefore unlikely to be readily penetrated by air to form pockets or layers of oxide, or oxide-saturated metal. (3) The stability of cementite may influence the rate of gas evolution by the form taken by the precipitate carbon. There is, however, no direct evidence that a surface skin of micro-chill is the main factor for the production of blistering defects.

Iron and Steel Plant for Turkey

It is reported from Ankara that the Turkish Sumer Bank and H. A. Brassert & Company, Limited, have signed a contract under which the latter will construct and equip the iron and steel works planned at Karabuk by the Turkish Government. It is estimated that the cost of the plant will be £2,500,000 and will have an annual output of 150,000 tons of iron and steel. It is understood that the contract was secured by the British firm in the face of severe competition from important German interests. The final implementing of the contract is contingent on approval by the Export Credits Guarantee Department of the Board of Trade as regards the financial clauses.

British Foundry School's Scottish Visit

The students of the British Foundry School visit foundries each week during the year's course, and it has been decided that an opportunity to see foundries further afield should be given, through an annual visit. The first of these visits took place recently to Scotland. The choice of works depended partly on transport considerations (ten plants being seen in four days), and partly on the desirability of including iron, steel and non-ferrous foundries as well as blast furnace plants. The general plan was drawn up by the honorary adviser to the School, Mr. J. G. Pearce, and the students were accompanied by the lecturer-in-charge, Mr. J. Bamford, and by Mr. H. Cowan, superintendent of the B.C.I.R.A. laboratory, the Falkirk Technical Institute, who made the detailed arrangements.

On the first day the two iron foundries and the steel foundry and other shops of Babcock & Wilcox, Limited, were seen at Renfrew, and the non-ferrous foundry and other shops of the same company at Dumbarton. The necessary transport to and from Glasgow and between the two works was kindly furnished by the company, which also entertained the visitors to lunch and tea and gave them an evening trip to Loch Lomond, the Gareloch and Loch Long. Their warm thanks are due to the managing director, Mr. A. McKinstry, and were expressed to Mr. W. H. Birks, works manager at Renfrew, and to Mr. L. Short, works manager at Dumbarton.

Colvilles, Limited's blast furnaces at Tollcross were visited next day, and a lecture on blast furnace practice was given by Mr. P. A. Abernethy (blast-furnace manager), who responded to a vote of thanks to the company. Subsequently, the Argus Foundry of G. & J. Weir, Limited, Cathcart, was visited, including both ferrous and non-ferrous departments. After tea, kindly provided by the company, a vote of thanks was responded to by Mr. C. A. Packer (apprentice trainer), Mr. N. McManus, M.B.E. (foundry manager), and Mr. J. Arnott, F.I.C. (metallurgist). Mr. Arnott subsequently lectured to the students on non-ferrous casting.

Three foundries in the Falkirk area, well known for the production of light castings, were also visited. At Smith & Wellstood, Limited, Bonnybridge, the visitors were received by Mr. G. A. Ure, J.P., managing director. The company kindly entertained the party to lunch in Falkirk, and Mr. H. McNair responded to a vote of thanks. At the works of the Falkirk Iron Company, Limited, the visitors were received by Mr. G. Scotland, director, and thanks were expressed to the company and to the managing director, Capt. W. J. Kennard. Finally the foundries and blast furnaces of Carron Company were inspected. The guides were Mr. Gillespie, Mr. Paton and Mr. A. Anderson (blast-furnace manager), who responded to the vote of thanks to the company and to Mr. Geo. Pate, O.B.E., managing director. Subsequently the Scottish Laboratory of the B.C.I.R.A. at Falkirk was visited, and Mr. H. Cowan, B.Sc., gave a lecture on light castings.

On the last day the party visited Leven. In the morning the foundry, patternshop and machine shops of the National Steel Foundry (1914), Limited, were seen and in the afternoon the foundry, enamelling plant and machine shops of Henry Balfour & Company, Limited, and their associated company, the Enamelled Metal Products Corporation (1933), Limited. Lunch was kindly provided jointly by the two companies and the students were welcomed by Mr. W. Moscrip, managing director of the National Steel Foundry (1914), Limited, and this was seconded by Mr. W. Lindsay Burns, managing director of Henry Balfour & Company, Limited, who were warmly thanked for their hospitality, and pro-

(*Concluded in next column.*)

(*Concluded from previous column.*)

vision of transport. To complete the tour, Mr. H. Cowan gave a second lecture on light castings.

The students were profoundly impressed by the energy and enterprise being shown in these Scottish establishments, and by the variety and quality of the work being carried out.

Students' Corner

SECOND SERIES

Cupola Practice—*(continued)*

Q. 20.—*What troubles are experienced especially when the cupola is in blast?*

A.—Dull iron, slow melting, scaffolding, difficulty when slagging-off, hard tapping-hole, and leakages with drop-bottoms are among the difficulties encountered.

Q. 21.—*What are the causes and remedies for such troubles?*

A.—Dull iron and slow melting may be the result of (1) inferior and insufficient fuel, or the bed-charge of coke being either too high or too low; (2) insufficient air entering the cupola in a given time, and (3) improper charging and fluxing.

Scaffolding is chiefly due to the charging of heavy scrap, coupled with the length of the pig-iron which may be too long and cause a bridging-over and jamming in the shaft of the cupola.

Difficulty when slagging-off may be attributed to (1) an insufficiency of flux or use of an unsuitable flux; (2) a blast tuyere too near the slagging hole, thus chilling or freezing the flow.

A hard tapping-hole is the result of the molten metal trickling into the hole and becoming solidified. This in turn is caused by (1) the hole, if closed when the blast is put on, being too long, (2) infrequent tapping out, (3) improper or dull melting at the start of the blow, and (4) blast stoppages.

Leakages with drop-bottom cupolas are usually the result of either (1) hard, or soft ramming of the sand bottom, (2) sand containing too much moisture, and (3) the sand comprising the bottom being too strong or too spent.

Q. 22.—*What is the cause of the hard iron which is sometimes encountered with the first tappings of a blow?*

A.—Generally the first metal melted, through being in contact with the bed-charge of coke, is high in sulphur, which causes hardness.

Q. 23.—*How does the molten iron sometimes find its way into the tuyeres and wind belt?*

A.—This occurrence is due to negligence of the cupola-man in charge. It happens when the slagging hole is purposely closed in order to get a large tap of iron in the hearth of the cupola. The level of the molten metal rises to the blast tuyere, and metal flows through it into the blast belt before the cupola-man can open the tapping hole. It is bad practice to take this risk. When the metal is up to the slagging hole it should be tapped out.

Q. 24.—*When the cupola is in operation a wool-like substance is occasionally seen floating about near the cupola. What is the explanation of this?*

A.—This is due to the action of the blast when in the direction of the molten slag, and is caused by continual poking at the tuyeres when the blast is on. Under these conditions the slag which is being formed just above the tuyeres is percolating through the incandescent coke, and because the tuyere is partly open when being poked, the blast plays on to the molten slag, and blows a very light slag wool into the air.

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The Week's News in Brief

Trade Talk

THE TENTH Annual General Meeting of the German Chemical Apparatus Society will be held in Munich on July 9 and 10.

GREENWOOD & HANSON, late of 89a, King's Road, Chelsea, London, S.W.3, have changed their address to 17, Bolan Street, Battersea, S.W.11.

THE RESULTS of the half-year's trading of the South African Iron and Steel Industrial Corporation are stated to be satisfactory. Progress has been made in output and quality.

BRITISH ROPES, LIMITED, whose Leith works were damaged by fire about two months ago, have decided to reconstruct the entire premises and install the latest machinery.

A NEW BASIC-IRON blast furnace has been started at Dorman Long & Company's Cleveland Works. The starting of this furnace brings the number in operation on the North-East Coast up to thirty.

WILLIAM DOXFORD & SONS, LIMITED, Sunderland, have received an order for a 9,200 tons motorship for the Chellew Steam Management Company. The engines will be supplied by the same firm.

DELEGATES to the Chemical Engineering Congress of the World Power Conference, held in London last week, made a pre-Congress visit to the Sheffield works of Firth-Vickers Stainless Steels, Limited.

A FOURTH BLAST FURNACE at the Derbyshire works of the Staveley Coal & Iron Company, Limited, has been relighted to cope with the expanding demand for pig-iron. The entire battery of four furnaces is now in blast.

JOHN M. HENDERSON & COMPANY, LIMITED, King's Works, Aberdeen, have received orders for two 80-100 tons overhead cranes for Davy Bros., Limited, Sheffield, and a 5-ton overhead crane for Thomas Firth & John Brown, Limited, Sheffield.

THE EDITOR wishes to thank Mr. J. E. Hurst (Past-President of the Institute of British Foundrymen), Mr. N. L. Evans and Mr. D. M. S. Parker for their kindness in sending along copies of the photographs which they took during the Scottish Conference.

THE INDUSTRIAL WELFARE SOCIETY has arranged a course of lectures on industrial law. The lectures, which last one hour, are being given at 14, Hobart Place, London, S.W.1, by Mr. H. Samuels, M.A., Barrister-at-Law. The course will commence on October 14, and a lecture will be delivered on every subsequent Wednesday at 6.30 p.m.

SWAN, HUNTER & WIGHAM RICHARDSON, LIMITED, of Wallsend, have obtained a contract from Newcastle owners for two motor cargo vessels. Each ship will carry 9,700 tons deadweight. The company has also secured an order from the Burmah Oil Company for an oil-tank motorship. The engines will be supplied by Swan Hunters' Neptune Works at Walker.

FOLLOWING THE FIRE which destroyed the premises of Beckett & Anderson, Limited, in Greendyke Street, Glasgow, on May 3, involving damage valued at more than £50,000, the firm of engineers have acquired new premises on a 3½-acre site at Rutherglen—the derelict mills of Stewarts and Lloyds, Limited, formerly belonging to the Scottish Tube Company.

CONGRATULATIONS ARE DUE to J. H. Sankey & Son, Limited, for the artistic lay-out of their new showrooms at Aldwych House, Aldwych, London, W.C.2. Exhibits which will attract the attention of foundrymen are those of the various refractories and cements (Pyruma) which are grouped about a surrealistic cupola. Any reader visiting the new showrooms can be assured of a warm welcome.

MR. R. B. WILLMOT, H.M. Trade Commissioner at Singapore, is at present in the United Kingdom on an official visit. Mr. Willmot will be available at the Department of Overseas Trade on July 6, 7 and 8 for the purpose of interviewing manufacturers and merchants interested in the export of United Kingdom goods to British Malaya, North Borneo, Sarawak and Brunei, after which he will commence a tour of a few of the more important centres in the provinces.

REDUCED UNEMPLOYMENT, higher wages and stronger funds are reported in the United Patternmakers' Association report for last year. The income was £54,624, and the surplus on the year's working was £8,885. Unemployed averaged 930, equal to 11 per cent. of the membership throughout the year, and the total paid in State and society benefit to the unemployed was £42,425, a reduction of £25,241 compared with 1934. The average wage increased from £3 2s. 6d. to £3 4s. The Association paid £15,820 in superannuation, and the net gain in membership for the year was 169.

THE LONDON OFFICE of the United Steel Companies, Limited, has been changed to 8 and 10, Grosvenor Gardens, Victoria, London, S.W.1. The telephone number is Sloane 4833. The office represents the following branches and associate companies: Steel, Peech & Tozer, Sheffield; Samuel Fox & Company, Limited, Sheffield; United Strip & Bar Mills, Sheffield; Appleby-Frodingham Steel Company, Limited, Scunthorpe; Daniel Doncaster & Sons, Limited, Sheffield; Workington Iron & Steel Company, Workington; The Rothervale Collieries, Treeton; United Coke and Chemicals Company, Limited, Workington; Thos. Butlin & Company Branch, Wellingborough.

A New Contemporary

The "Engineer and Foundryman" (South Africa) is the title of a new magazine to be published monthly from Magor House, 74, Fox Street, Johannesburg. The subscription rate is 10s. 6d. per annum or 1s. per copy. It is the official organ of five associations, including the Engineers' and Founders' Association. Appropriately enough, the first article in the first issue, dated June, "Then and Now," reviews the history of the Rand as an engineering centre and calls to mind such personalities as Peter Boag, John Wright, Alan B. McKay, W. H. Batten, H. H. Blanchard, J. A. Duree and F. Bell. There are two full-length technical articles, one by C. G. Bainbridge on "Cutting Steel with Oxygen Machines" and the other on "Bearing Metals" by A. K. Gold. There is a fine cartoon of Mr. A. H. Guy who is at present in England, and the market news is both ample and reliable. We congratulate our young contemporary and wish it a long and useful career of service to the South African engineering and foundry industries.

Company Reports

Greenwood & Batley, Limited.—Ordinary dividend for the year to March 31 of 4½ per cent.

Hammond Lane Foundry Company, Limited.—Interim dividend of 5 per cent. on the ordinary shares.

W. & T. Avery, Limited.—Final dividend on the ordinary shares of 10 per cent., making 15 per cent. for the year to March 31.

Glacier Metal Company, Limited.—Profit to February 29, after depreciation and directors' fees, £33,855; brought in, £10,069; income tax, £5,532; dividend on preference shares from December 12, 1935, to February 29 last, £1,194; capitalisation at December 6, 1935, out of profits of the year, £10,000; costs of increasing capital written off, £1,435; to reserve £4,000; dividend of 10 per cent. on the ordinary shares, £11,437; carried forward, £10,325.

Bradley & Foster, Limited.—Net profit, after providing interest on debentures and directors' fees, £11,165; dividend from subsidiary company, £4,000; provision for taxation, £2,722; to depreciation reserve fund, £10,402; brought in, £3,536; interim dividend on preferred ordinary shares at 3 per cent. actual, £157; final dividend on preferred ordinary shares at 5½ per cent. actual, £283; dividend on ordinary shares for year at 5 per cent., £1,906; carried forward, £3,231. The allocation of £10,402 to the depreciation reserve fund brings up that fund to a total of £23,723, the whole of which has been applied to writing down the freehold land, buildings, works, and effects at Darlaston.

Personal

MR. OLIVER SMALLEY, H.M. Consul at Pittsburgh, is arriving in England next Monday.

MR. J. F. PHILLIPS has been appointed a director of the Universal Grinding Wheel Company, Limited.

MAJOR H. R. KILNER, general manager of the Crayford and Dartford Works of Vickers-Armstrongs, Limited, has been appointed a director of the company.

MR. VICTOR STOBIE has changed his home address from Langholme, South Drive, Harrogate, to Dunston House, South Park Road, Harrogate. His telephone number is Harrogate 6075.

MR. P. MURDOCH, shift manager of the Consett Iron Company, Limited, is leaving to take up the position as manager of the Newton Steelworks of the Steel Company of Scotland, Limited.

MR. JAMES LEGGATE, foreman iron dresser with Pott, Cassels & Williamson, Motherwell, has been presented with a writing bureau by his colleagues on the occasion of his retirement after 42 years' service.

SIR ROBERT MOND, who was recently awarded the "Messel" Medal of the Society of Chemical Industry in Great Britain, has been elected President of the Société de Chimie Industrielle of France.

THE GOLDEN WEDDING of Dr. and Mrs. William Stroud, Milngavie, was celebrated last week. Dr. Stroud is joint founder and present chairman of Barr & Stroud, Limited, engineers and instrument makers, of Glasgow.

COMMANDER E. R. MICKLEM, R.N., general manager of the Elswick Works, Newcastle-upon-Tyne, of Vickers-Armstrongs, Limited, has been appointed a director of the firm. Commander Micklem has been general manager of the works since 1928, and he will continue in this capacity.

DR. A. C. FIELDNER, chief engineer of the Experiment Stations Division of the U.S. Bureau of Mines, Washington, D.C., has been elected President of the American Society for Testing Materials, and DR. T. G. DELBRIDGE, manager of the Research and Development Department of the Atlantic Refining Company, Philadelphia, Pa., has been elected Vice-President.

Will

HUNT, FRANK, chairman of R. Hunt & Company, Limited, Atlas Engineering Works, Earls Colne, Essex £134,969

Obituary

MR. ALEXANDER SPENCER, one of the oldest members of the Institute of Mechanical Engineers, died recently at the age of 77.

WE REGRET to record the death of Mr. E. P. Taudevin, which occurred suddenly last Thursday night. He was well known all over Western Europe as a furnace designer. For many years he was a consulting engineer, and latterly acted as technical representative for Gibbons Bros., Limited, of Dudley. In recent years he made a number of contacts with the malleable foundry industry in connection with a new type of annealing furnace he had developed.

Contract Open

Bagdad, August 4.—Cast or spun iron spigot and socket pipes, for the Bagdad District Water Board. The Department of Overseas Trade. (Reference T.Y. 30,399.)

Forthcoming Events

Institute of British Foundrymen

JULY 8.

London Branch:—Visit to Britannia Iron & Steel Works, Limited, and W. H. Allen, Sons & Company, Limited, Bedford.

JULY 9.

East Anglian Section:—Visit to Ransomes & Rapier, Limited, Ipswich.

Reavell & Company Ltd.

COMPRESSORS & EXHAUSTERS OF ALL TYPES FOR AIR OR GASES

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INDIA AND HOME OFFICES.

DATE 25th.Feb. 1936.

REFERENCE AGP/EB.

Messrs. Foundry Engineers, Ltd.,
HALIFAX.
Yorks.

Dear Sirs,

In reply to your letter of the 13th.instant, we enclose herewith the two negatives of the Foundry Plant you recently installed for us.

We may say that the Plant continues to give satisfaction and we are obtaining the following output:-

Green Sand	-	25 cwts. per hour.
Facing Sand	-	25 " "
Oil Sand.	-	15 " "

The plant is well ahead of our requirements and is running daily.

Yours faithfully,
REAVELL & CO.LTD.

encl.2 negatives.

Raw Material Markets

It is a source of satisfaction to producers in the iron and steel trades that they are now able to devote more of their output to the demands of overseas buyers. Home transactions continue to keep makers fully occupied, but recent shipments abroad have involved substantial tonnages. Several large pig-iron producers have increased their outputs and, although supply remains under the demand, conditions are less urgent and contracts for deliveries during the second half of the year have been made. As from July 1, the premium of 5s. previously in operation for deliveries of pig-iron after that date has become merged into the zone prices, which are increased accordingly in all areas by 5s. a ton.

Pig-Iron

MIDDLESBROUGH.—Deliveries of Cleveland foundry iron have been on an increased scale following enlarged outputs from the makers, but they remain considerably behind schedule. Business for the second half of the year has been arranged on a good scale at the revised price basis which came into operation yesterday. The minimum values of No. 3 Cleveland G.M.B. are 75s. per ton delivered Middlesbrough or Falkirk, 77s. on the North-East Coast, and 78s. in Glasgow, while No. 1 foundry quality is 2s. 6d. per ton more, and No. 4 foundry 1s. per ton less than the figure for No. 3.

Most of the makers of hematite in this area have sold the larger part of their output to the end of the year. Home trade is considered before export inquiries and, consequently, the tonnage being shipped abroad only involves a small quantity. Quotations for No. 1 East Coast hematite are 85s. 6d. per ton delivered Scotland, North-East Coast or Middlesbrough, 91s. in Sheffield, and 96s. 6d. in Birmingham, subject to a rebate of 5s.

LANCASHIRE.—Deliveries of pig-iron in this area have been very heavy recently, but now that the advanced prices are ruling it is expected that users will not press the makers so urgently. New business is confined to deliveries before the commencement of next year, but few contracts have been concluded. For delivery to Lancashire consumers prices of Derbyshire, Staffordshire and Lancashire brands of No. 3 foundry iron are on the basis of 83s. per ton, with Northants at 81s. 6d. Scottish foundry iron is quoted at about 90s. per ton delivered in the Manchester area, with West Coast hematite offered at 93s. 6d., and East Coast material at 93s., both delivered equal to Manchester and subject to rebate.

MIDLANDS.—Midland brands of iron continue to be in heavy request and the furnaces, in some cases, have more specifications on hand than they can cope with at the present time. The revised minimum values are 77s. 6d. for Northants No. 3 and 80s. for Derbyshire, Lincolnshire and North Staffordshire No. 3, delivered to Birmingham and Black Country stations and carrying a small sliding-scale rebate to large users. Any supplies of forge pig-iron that become available are immediately taken up by local ironmakers, who are very short of this material. The price basis is unchanged, namely, 5s. per ton below No. 3 foundry iron if used for puddling, but only 3s. less for the foundries. Special grades of iron are well inquired for, the motor-car makers and many engineers taking up large tonnages. Prices are without control, but this position may be altered in the near future. Meanwhile, low-phosphorus iron is quoted at 92s. 6d. to 100s. per ton, medium-phosphorus 80s. to 87s. 6d., and refined irons from £6 10s. to £7 15s. per ton delivered South Staffordshire. Supplies of hematite continue to be below the requirements of the engineers and ironfounders, whose activity, as a result, is being handicapped. New contracts are having to be refused by the makers. West Coast mixed numbers are quoted at £4 17s., East Coast at £4 16s., and Welsh mixed numbers at £4 15s. 6d., delivered stations in the Black Country and subject to an additional 1s. 6d. per ton if delivered into local works. These prices are subject to a rebate of 5s. per ton.

SCOTLAND.—The output of pig-iron in this area has been enlarged by the blowing-in of a furnace which is to make basic iron. As a result of this increase 15 furnaces are now producing pig-iron in the Scottish area, four on basic, five on hematite and six on foundry. Basic iron imports from India and Russia have been made during the week. No. 3 foundry is quoted at 79s. f.o.t. furnaces, with 2s. 6d. extra for No. 1. No. 3 Cleveland iron is now at 75s. f.o.t. Falkirk and 78s. f.o.t. Glasgow. Supplies of the latter brand of iron are almost negligible and large tonnages have been acquired from other areas. Steelworks are being hard pressed for supplies of steel-making irons. The official prices of steel-making irons are as follow:—Mixed numbers East Coast, West Coast and Scottish hematite, 85s. 6d.; basic, British and Indian, 75s., all less 5s. rebate, delivered steelworks here.

Coke

The strength of the foundry-coke market is unimpaired, and there is very little likelihood of any price reductions being made. Many contracts involving delivery up to the end of the year have been made and a few have exceeded this period. For delivery in Birmingham and district best Durham coke is offered at from 41s. 6d. to 43s., and Welsh coke from 39s. to 50s. per ton, the latter varying considerably according to quality.

Steel

There is no sign of any slackening in the busy conditions that have prevailed for some weeks in practically every department of the steel trade, says the official report of the London Iron and Steel Exchange. The usual seasonal decline in demand has shown no signs of developing, and consumers are offering business on a scale that, in some sections of the trade, is embarrassing to the manufacturers. In the semi-finished steel department, in spite of the increase in output, some stringency has again developed in the market. Consumers are pressing for supplies, and the full production of the British works is going into immediate use. Difficulty is experienced in obtaining prompt supplies, and in some cases producing works are unable to accept orders owing to the congested state of their order-books. Business in finished steel continues at the high level which has ruled for the past week or two, and consumers are anxious to buy far forward. The manufacturers, however, are pursuing a cautious policy, and many of them are concentrating upon overtaking arrears in deliveries. Business with oversea markets has shown rather more life, but little surplus material is left for export when the home market is satisfied.

Scrap

The supply position in the Cleveland area has greatly improved and the acute conditions that have prevailed for several months have been relieved. New business is of little consequence, consumers awaiting the termination of existing contracts. Good heavy melting steel is still quoted at 57s. 6d. per ton delivered, while the prices of machinery metal and heavy foundry cast iron are also unchanged at 65s. and 62s. 6d. per ton respectively. Clean, light cast iron is offered at 54s. Most descriptions of iron and steel scrap are in good request on the Midland market, but quotations are too firm to tempt very much new business. Heavy, unsheared wrought iron is at 67s. 6d. to 70s., while there is a good deal of activity in heavy machinery metal, in cupola sizes, at 70s., good heavy at 65s. and clean light at 52s. 6d. to 55s. Short, heavy steel, suitable for use in the foundries, is at 67s. 6d. to 70s. per ton, delivered works. Conditions on the Lancashire market remain active, firm prices prevailing. Cast-iron scrap is quoted at 62s. 6d., with machinery metal at 67s. 6d. The very warm weather has caused a temporary decrease in the number of inquiries for heavy wrought iron, but the value is maintained around 65s. Heavy melting steel scrap is about 55s. per ton, delivered Sheffield basis. Consumption of scrap material is on a good scale in the Scottish area and quotations have remained steady. Heavy steel is at 57s. 6d. per ton, while heavy basic, or heavy iron and steel scrap mixed, is at 52s. 6d. Wrought-iron piling material has eased a trifle and is quoted at 69s. to 70s., while for special quality 2s. 6d. to 3s. 6d. more is obtainable. Heavy machinery cast-iron scrap, in pieces not exceeding 1 cwt., is 68s. 6d. to 70s., and ordinary cast iron, to the same specification, is around 65s. to 66s. per ton, delivered f.o.t. consumers' works.

Metals

Copper.—This market has had a steady appearance and buying has been on an improved scale, following the expectations of the raising of sanctions imposed against Italy and also the more hopeful outlook in connection with the Continental labour disputes. The position of the market statistically is considered to be quite sound. World stocks of refined copper declined from 485,500 short tons on January 1, 1936, to 466,132 tons at the end of May. Conditions on the United States market remain dull and buying is on a low scale, being about 500 tons per day so far as domestic sales are concerned. Deliveries, however, are very heavy.

Daily market prices:—

Cash.—Thursday, £36 13s. 9d. to £36 15s.; Friday, £36 12s. 6d. to £36 13s. 9d.; Monday, £36 10s. to £36 11s. 3d.; Tuesday, £36 10s. to £36 12s. 6d.; Wednesday, £36 11s. 3d. to £36 12s. 6d.

Three Months.—Thursday, £37 to £37 1s. 3d.; Friday, £36 17s. 6d. to £36 18s. 9d.; Monday, £36 15s. to £36 16s. 3d.; Tuesday, £36 16s. 3d. to £36 17s. 6d.; Wednesday, £36 16s. 3d. to £36 17s. 6d.

Tin.—The decision of the International Tin Committee, made at its meeting in Paris on Thursday of last week, to raise the quota by 5 per cent. for the July-September quarter was unexpected and as a result the price of cash tin fell £9 5s. on Friday. Undoubtedly the increased quota decision was influenced by the failure of Bolivia to fulfil her quota. The next meeting of the committee was fixed for September 4 and is to be held in London. According to the June issue of the bulletin published by the Hague Statistical Office of the International Tin Research and Development Council, the apparent world consumption of tin in April, 1936, was 11,895 tons. This is about 2,000 tons below the previous month, but more than 300 tons above April last year. For the year to April 30 last, the apparent world consumption of tin totalled 148,642 tons, an increase of 25,023 tons over the previous year. World production of the metal for the year to April last is given as 147,099 tons, against 119,596 tons for the preceding 12 months.

Metal Exchange quotations were as follow:—

Cash.—Thursday, £185 15s. to £186; Friday, £176 10s. (buyers); Monday, £176 15s. to £177 10s.; Tuesday, £178 15s. to £179 5s.; Wednesday, £178 5s. to £178 10s.

Three Months.—Thursday, £183 to £183 5s.; Friday, £174 5s. to £174 10s.; Monday, £173 15s. to £174; Tuesday, £175 15s. to £176; Wednesday, £175 5s. to £175 10s.

Spelter.—Rather more confidence has been shown in this market recently and buying interest has increased, while consumption is reported to have been well maintained. Quiet conditions have prevailed on the Continent, while buying in the United States has been low. The latest, but still unofficial, reports concerning the re-establishment of the Cartel are that "definite progress has been made and that a successful result may be achieved during the course of a few months."

Official quotations were as follow:—

Ordinary.—Thursday, £14; Friday, £13 15s.; Monday, £13 13s. 9d.; Tuesday, £13 13s. 9d.; Wednesday, £13 7s. 6d.

Lead.—Little change has occurred on the lead market, which has a firm tone. Consumption is well maintained and trade demand, especially from the building industry, is heavy. Buying in the United States does not amount to any substantial tonnage.

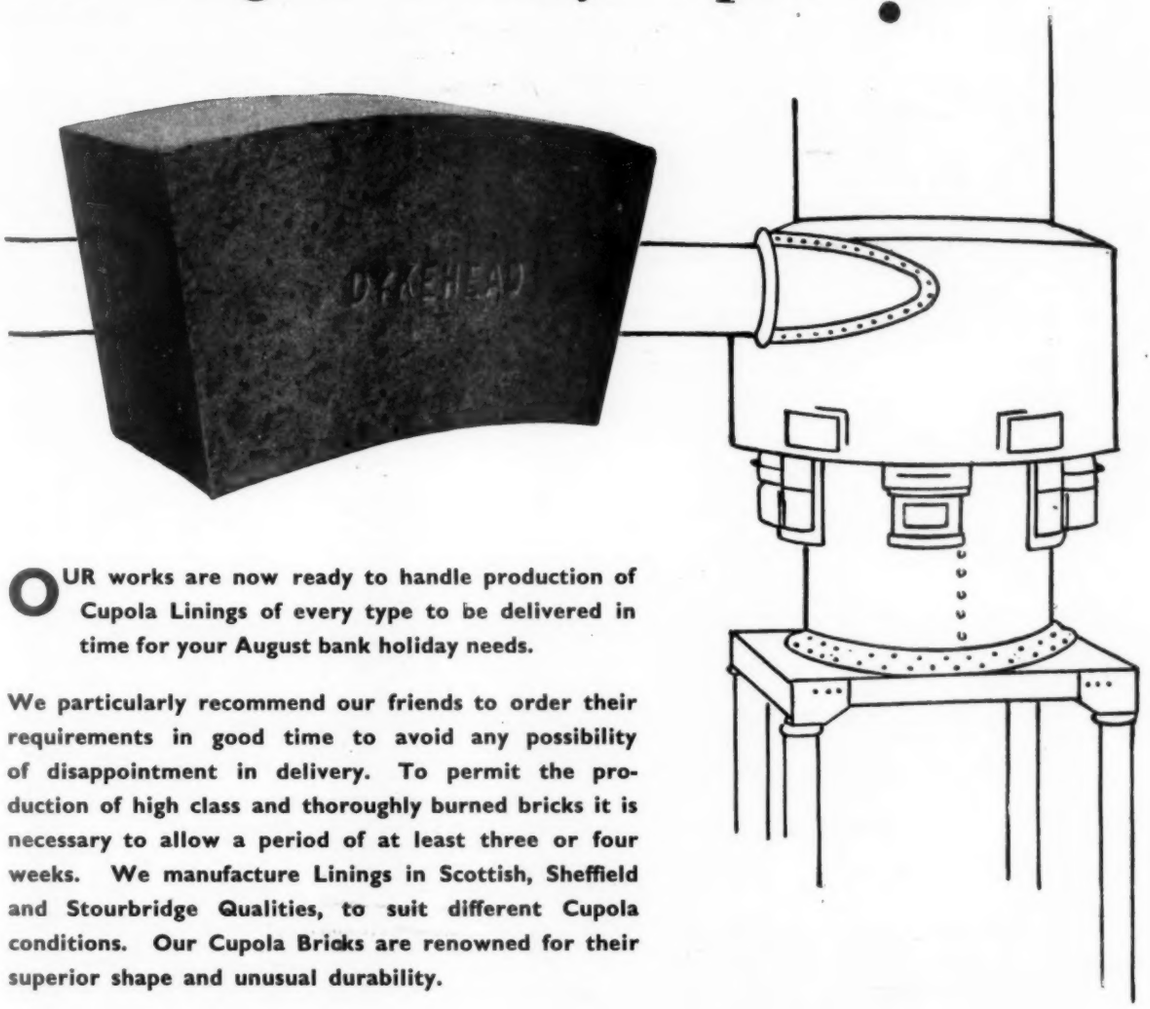
Day-to-day quotations:—

Soft Foreign (Prompt).—Thursday, £15 2s. 6d.; Friday, £15 1s. 3d.; Monday, £15 1s. 3d.; Tuesday, £15 2s. 6d.; Wednesday, £15 3s. 9d.

MR. HERBERT HOWARD GREENWAY, a director of Gaskell & Chambers, Limited, brassfounders, etc., of Birmingham, has died, aged 75. Mr. Greenway resigned his managing directorship about six years ago, but remained on the board. His son, Mr. Noel W. Greenway, consulting engineer and director of Gaskell & Chambers, Limited, died suddenly a week or so ago.

PUBLIC LIBRARY DETROIT MICH.

NOW is the time to order CUPOLA LININGS for August holiday repairs!



OUR works are now ready to handle production of Cupola Linings of every type to be delivered in time for your August bank holiday needs.

We particularly recommend our friends to order their requirements in good time to avoid any possibility of disappointment in delivery. To permit the production of high class and thoroughly burned bricks it is necessary to allow a period of at least three or four weeks. We manufacture Linings in Scottish, Sheffield and Stourbridge Qualities, to suit different Cupola conditions. Our Cupola Bricks are renowned for their superior shape and unusual durability.

Please write, phone or call for further particulars.

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Telephone: 5250.
Telegrams:
"Genefax, Glasgow."

South Wales Office:
11, Wind St.,
Swansea.
Telephone: 3680.
Telegrams:
"Genefax, Swansea."

RAW MATERIALS—PRICE LIST

(Wednesday, July 1, 1936)

COPPER

	£ s. d.
Standard cash	36 11 3
Three months	36 16 3
Electrolytic	40 10 0
Tough	39 0 0
Best selected	39 10 0
Sheets	68 0 0
India	49 15 0
Wire bars	40 17 6
Ingot bars	40 17 6
H.C. wire rods	44 7 6
Off. av. cash, June	36 7 2¾
Do., 3 mths., June	36 13 0¼
Do., Sttlmnt., June	36 6 10⅝
Do., Electro, June	40 11 3
Do., B.S., June	39 19 2
Do., wire bars, June	40 15 4½
Solid drawn tubes	10½d.
Brazed tubes	10½d.
Wire	6½d.

BRASS

Solid drawn tubes	9½d.
Brazed tubes	11½d.
Rods, drawn	8½d.
Rods, extd. or rlld.	8d.
Sheets to 10 w.g.	8d.
Wire	7½d.
Rolled metal	7½d.
Yellow metal rods	5d.
Do. 4 × 4 Squares	5½d.
Do. 4 × 3 Sheets	5½d.

TIN

	£ s. d.
Standard cash	178 5 0
Three months	175 5 0
English	178 10 0
Bars	179 10 0
Straits	179 5 0
Australian (nom.)	—
Eastern	177 5 0
Banca	179 5 0
Off. av. cash, June	183 6 10⅝
Do., 3 mths., June	181 1 2¾
Do., Sttlmt., June	183 5 8⅞

SPELTER

	£ s. d.
Ordinary	13 7 6
Remelted	13 0 0
Hard	11 0 0
Electro 99.9	15 5 0
English	14 10 0
India	12 10 0
Zinc dust	19 10 0
Zinc ashes	4 5 0
Off. aver., June	14 0 2⅞
Aver. spot, June	13 17 11

LEAD

	£ s. d.
Soft foreign ppt.	15 3 9
Empire	15 17 6
English	17 5 0
Off. average, June	15 4 3⅜
Average spot, June	15 3 4⅞

ALUMINIUM

Ingots	£100 to £105
Wire	1/3 to 1/4 lb.
Sheet and foil	1/2 to 1/4 lb.

ZINC SHEETS, &c.

	£ s. d.
Zinc sheets, English	23 10 0 to 24 0 0
Do., V.M. ex-whse.	23 10 0 to 24 0 0
Rods	26 0 0

ANTIMONY

	£ s. d.
English	66 10 0 to 67 10 0
Chinese, ex-whse.	51 0 0
Crude, c.i.f.	24 0 0

QUICKSILVER

	£ s. d.
Quicksilver	11 12 6 to 12 2 0

FERRO-ALLOYS AND STEEL-MAKING METALS

Ferro-silicon—	
25%	8 17 6
45/50%	12 15 0
75%	17 17 6
Ferro-vanadium—	
35/50%	12/8 lb. Va.
Ferro-molybdenum—	
70/75% carbon-free	4/6 lb. Mo.
Ferro-titanium—	
20/25% carbon-free	9d. lb.
Ferro-phosphorus, 20/25%	£21 0 0 to £22 0 0
Ferro-tungsten—	
80/85%	3/- lb.
Tungsten metal powder—	
98/99%	3/3 lb.
Ferro-chrome—	
2/4% car.	33 0 0
4/6% car.	21 10 0
6/8% car.	21 0 0
8/10% car.	21 0 0
Ferro-chrome—	
Max. 2% car.	33 10 0
Max. 1% car.	36 5 0
Max. 0.70% car.	37 5 0
70% carbon-free	9½d. lb.
Nickel—99.5/100%	£200 to £205
"F" nickel shot	£184 0 0
Ferro-cobalt, 98/99%	6/3 to 6/9 lb.
Metallic chromium—	
96/98%	2/5 lb.
Ferro-manganese (net)—	
76/80% loose	£11 5 0 to 11 15 0
76/80% packed	£12 5 0 to 12 15 0
76/80% export	(nom.) £10 5 0
Metallic manganese—	
94/96% carbon-free	1/3 lb.

Per ton unless otherwise stated, basis 2-ton lots.

HIGH-SPEED TOOL STEEL

Finished bars, 14% tungsten	2s. 0d.
Finished bars, 18% tungsten	2s. 9d.

Per lb. net, d/d buyers' works.

Extras—

Rounds and squares, 3 in. and over	4d. lb.
Rounds and squares, under ½ in. to ¼ in.	3d. lb.
Do., under ¼ in. to 1/16 in.	1/- lb.
Flats, ¼ in. × ¼ in. to under 1 in. × ⅛ in.	3d. lb.
Do., under ¼ in. × ¼ in.	1/- lb.
Bevels of approved sizes and sections	6d. lb.

Bars cut to length, 10% extra.

SCRAP

	£ s. d.	£ s. d.
South Wales—		
Heavy steel	3 2 0	to 3 4 0
Mixed iron and steel	2 18 0	to 3 0 0
Heavy cast iron	2 18 0	to 3 0 0
Good machinery	3 2 0	to 3 5 0
Cleveland—		
Heavy steel		2 17 6
Steel turnings		2 0 0
Heavy cast iron		3 2 6
Heavy machinery		3 5 0
Midlands—		
Light cast-iron scrap	2 12 6	to 2 15 0
Heavy wrought iron	3 7 6	to 3 10 0
Steel turnings		2 0 0
Scotland—		
Heavy steel		2 17 6
Ordinary cast iron	3 5 0	to 3 6 0
Engineers' turnings		2 2 6
Cast-iron borings		1 17 6
Wrot-iron piling		3 9 6
Heavy machinery		3 8 6

London—Merchants' buying prices, delivered yard.

	£ s. d.
Copper (clean)	29 0 0
Brass	19 0 0
Lead (less usual draft)	13 10 0
Tea lead	9 0 0
Zinc	8 10 0
New aluminium cuttings	74 0 0
Braziery copper	26 0 0
Gunmetal	27 0 0
Hollow pewter	130 0 0
Shaped black pewter	108 0 0

PIG-IRON

N.E. Coast (d/d Tees-side area)—

Foundry No. 1	77/6
,, No. 3	75/-
,, No. 4	74/-
Forge No. 4	74/-
Hematite No. 1	85/6*
Hematite M/Nos.	85/-*

N.W. Coast—

Hem. M/Nos. d/d Glas.	85/6*
,, d/d Birm.	97/-*
Malleable iron d/d Birm.	125/-

Midlands (d/d Birmingham dist.)—

Staffs No. 4 forge	77/-
,, No. 3 fdry.	80/-
Northants forge	74/6
,, fdry. No. 3	77/6
,, fdry. No. 1	80/6
Derbyshire forge	77/-
,, fdry. No. 3	80/-
,, fdry No. 1	83/-

Scotland—

Foundry, No. 1, f.o.t.	81/6
,, No. 3, f.o.t.	79/-
Cleveland No. 3, Glasgow	78/-
,, ,, Falkirk	75/-
Scottish hem. M/Nos. d/d	85/6*

Sheffield (d/d district)—

Derby forge	74/6
,, fdry. No. 3	77/6
Lincs forge	74/6
,, fdry. No. 3	77/6
W.C. hematite	91/-*

Lancashire (d/d eq. Man.)—

Derby fdry. No. 3	83/-
Staffs fdry. No. 3	83/-
Northants fdry. No. 3	81/6
Cleveland fdry. No. 3	83/-
Dalzell, No. 3 (special)	107/6 to 110/-
Glengarnock, No. 3	90/-
Clyde, No. 3	90/-
Monkland, No. 3	90/-
Summerlee, No. 3	90/-
Eglinton, No. 3	90/-
Gartsherrie, No. 3	90/-
Shotts, No. 3	90/-

* Subject to a rebate of 5s. per ton under certain conditions

FINISHED IRON AND STEEL

Usual district deliveries for iron; delivered consumer's station for steel.

Iron—	£ s. d.	£ s. d.
Bars (or.)		10 2 6
Nut and bolt iron	8 10 0	to 9 0 0
Hoops		11 0 0 and up.
Marked bars (Staffs) f.o.t.		12 10 0
Gas strip		11 0 0 and up.
Bolts and nuts, ¾ in. × 4 in.		15 15 0 and up.
Steel—		
Plates, ship, etc.	9 7 6	to 9 10 0
Boiler plts.	9 17 6	to 10 0 0
Chequer plts.		11 0 0
Angles		9 0 0
Tees		10 0 0
Joists		9 7 6
Rounds and squares, 3 in. to 5½ in.		10 0 0
Rounds under 3 in. to ¼ in. (Untested)		9 7 0
Flats—8 in. wide and over		9 5 0
,, under 8 in. and over 5 in.		9 10 0
Rails, heavy	8 5 0	to 8 10 0
Fishplates		12 10 0
Hoops (Staffs)		10 2 0
Black sheets, 24g. (4-t. lots)		11 10 0
Galv. cor. shts. (,,)		13 10 0
Galv. flat shts. (,,)		14 0 0
Galv. fencing wire, 8g. plain		15 0 0
Billets, soft	6 2 6	and up.
Billets, hard	7 2 6	to 7 7 6
Sheet bars		6 0 0
Tin bars		6 0 0

PHOSPHOR BRONZE

	Per lb. basis
Strip	10½d.
Sheet to 10 w.g.	11½d.
Wire	12½d.
Rods	11½d.
Tubes	14d.
Castings	12½d.

Delivery 3 cwt. free.
10% phos. cop. £30 above B.S.
15% phos. cop. £35 above B.S.
Phosphor tin (5%) £30 above price of English ingots.
C. CLIFFORD & SON, LIMITED.

NICKEL SILVER, &c.

	Per lb.
Ingots for raising	7d. to 1/1
Rolled—	
To 9 in. wide	1/1 to 1/7
To 12 in. wide	1/1½ to 1/7½
To 15 in. wide	1/1½ to 1/7½
To 18 in. wide	1/2 to 1/8
To 21 in. wide	1/2½ to 1/8½
To 25 in. wide	1/3 to 1/9
Ingots for spoons and forks	7d. to 1/3½
Ingots rolled to spoon size	10d. to 1/6½
Wire round—	
to 10g.	1/4½ to 1/11½

with extras according to gauge.
Special 5ths quality turning rods in straight lengths, 1/3½ upwards.

AMERICAN IRON AND STEEL

At Pittsburgh unless otherwise stated.

	Dols.
No. 2 foundry, Phila.	21.31
No. 2 foundry, Valley	19.50
No. 2 foundry, Birm.	15.50
Basic, Valley	19.00
Malleable, Valley	19.50
Grey forge, Valley	19.00
Ferro-mang. 80%, seaboard	75.00
O.-h. rails, h'y, at mill	36.37½
Billets	28.00
Sheet bars	28.00
Wire rods	38.00
	Cents.
Iron bars, Chicago	1.80
Steel bars	1.85
Tank plates	1.80
Beams, etc.	1.80
Skelp, grooved steel	1.80
Steel hoops	2.10
Sheets, black, No. 24	2.40
Sheets, galv., No. 24	3.10
Wire nails	2.10
Plain wire	2.40
Barbed wire, galv.	2.60
Tinplates, 100-lb. box	$5.25

COKE (at ovens)

Welsh foundry	30/- to 31/-
,, furnace	24/6 to 25/-
Durham foundry	25/- to 26/-
,, furnace	22/6
Scotland, foundry	30/-
,, furnace	25/- to 26/-

TINPLATES

f.o.b. Bristol Channel ports.

I.C. cokes 20×14 per box	18/9
,, 28×20 ,,	37/6
,, 20×10 ,,	26/9 to 27/-
,, 18¾×14 ,,	19/6
C.W. 20×14 ,,	15/6 to 15/9
,, 28×20 ,,	33/9 to 34/-
,, 20×10 ,,	22/6 to 22/9
,, 18¾×14 ,,	15/3 to 15/9

SWEDISH CHARCOAL IRON & STEEL

	£ s. d.	£ s. d.
Pig-iron	£6 0 0	to £7 0 0
Bars-hammered, basis	£16 0 0	to £16 10 0
Bars and nail-rods, rolled, basis	£15 15 0	to £16 0 0
Blooms	£10 0 0	to £12 0 0
Keg steel	£30 0 0	to £31 0 0
Faggot steel	£18 0 0	to £23 0 0
Bars and rods dead soft, st'l	£10 0 0	to £12 0 0

All per English ton, f.o.b. Gothenburg.
[Subject to an exchange basis of Kr. 18.16 to £1.]

DAILY FLUCTUATIONS

Standard Copper (cash)

	£	s.	d.		
June 25 ..	36	13	9	inc.	2/6
„ 26 ..	36	12	6	dec.	1/3
„ 29 ..	36	10	0	„	2/6
„ 30 ..	36	10	0	No	change
July 1 ..	36	11	3	inc.	1/3

Electrolytic Copper

	£	s.	d.		
June 25 ..	40	15	0	No	change
„ 26 ..	40	15	0	„	„
„ 29 ..	40	10	0	dec.	5/-
„ 30 ..	40	12	6	inc.	2/6
July 1 ..	40	10	0	dec.	2/6

Standard Tin (cash)

	£	s.	d.		
June 25 ..	185	15	0	inc.	5/-
„ 26 ..	176	10	0	dec.	185/-
„ 29 ..	176	15	0	inc.	5/-
„ 30 ..	178	15	0	„	40/-
July 1 ..	178	5	0	dec.	10/-

Tin (English ingots)

	£	s.	d.		
June 25 ..	185	15	0	inc.	10/-
„ 26 ..	176	10	0	dec.	185/-
„ 29 ..	177	0	0	inc.	10/-
„ 30 ..	179	0	0	„	40/-
July 1 ..	178	10	0	dec.	10/-

Spelter (ordinary)

	£	s.	d.		
June 25 ..	14	0	0	inc.	1/3
„ 26 ..	13	15	0	dec.	5/-
„ 29 ..	13	13	9	„	1/3
„ 30 ..	13	13	9	No	change
July 1 ..	13	7	6	dec.	6/3

Spelter (Electro, 99.9 per cent.)

	£	s.	d.		
June 25 ..	16	1	3	inc.	1/3
„ 26 ..	15	17	6	dec.	3/9
„ 29 ..	15	15	0	„	2/6
„ 30 ..	15	11	3	„	3/9
July 1 ..	15	5	0	„	6/3

Lead (soft foreign, prompt)

	£	s.	d.		
June 25 ..	15	2	6	dec.	2/6
„ 26 ..	15	1	3	„	1/3
„ 29 ..	15	1	3	No	change
„ 30 ..	15	2	6	inc.	1/3
July 1 ..	15	3	9	„	1/3

Lead (English)

	£	s.	d.		
June 25 ..	17	5	0	No	change
„ 26 ..	17	0	0	dec.	5/-
„ 29 ..	17	0	0	No	change
„ 30 ..	17	0	0	„	„
July 1 ..	17	5	0	inc.	5/-

AVERAGE MONTHLY PRICES OF STEEL RAILS

Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Yearly average
	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.
1921	23 5 0	20 4 0	18 0 0	17 0 0	15 0 0	15 0 0	14 0 0	14 0 0	14 0 0	11 12 6	10 10 0	10 0 0	15 4 3
1922	9 10 0	9 10 0	9 10 0	9 10 0	9 10 0	9 10 0	9 10 0	9 0 0	8 15 0	8 15 0	8 15 0	8 15 0	9 4 2
1923	8 17 6	9 2 0	10 5 0	10 10 0	10 10 0	10 10 0	9 15 0	9 0 0	8 15 0	8 15 0	8 19 0	9 5 0	9 9 10
1924	9 5 0	9 5 0	9 5 0	9 5 0	9 5 0	9 2 6	9 0 0	9 0 0	9 0 0	9 0 0	9 0 0	9 0 0	9 2 3½
1925	9 0 0	9 0 0	9 0 0	9 0 0	8 15 0	8 10 7½	8 10 0	8 10 0	8 10 0	8 4 0	8 0 0	8 0 0	8 11 7½
1926	8 0 0	8 0 0	8 0 0	8 0 0	8 0 0	8 0 0	8 0 0	8 7 6	8 10 0	8 10 0	8 10 0	8 10 0	8 3 11½
1927	8 10 0	8 10 0	8 10 0	8 2 6	8 2 6	8 2 6	8 2 6	8 2 6	8 2 6	8 3 0	8 5 0	8 5 0	8 4 10
1928	8 5 0	8 5 0	8 5 0	8 5 9	8 6 3	8 6 3	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0	8 7 9½
1929	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0
1930	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0
1931	8 9 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 8
1932	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6
1933	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6
1934	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6
1935	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6
1936	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	—	—	—	—	—	—	—

AVERAGE MONTHLY PRICES OF EAST COAST HEMATITE AT MIDDLESBROUGH

Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Average
	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.
1920	220 0	220 0	240 0	260 0	260 0	260 0	260 0	260 0	260 0	200 0	200 0	260 0	251 8
1921	240 0	220 0	180 0	180 0	180 0	160 0	160 0	160 0	137 0	127 6	117 6	104 6	162 2
1922	97 6	91 7½	100 0	98 6	97 1½	94 7	93 6	90 9	89 7	91 10½	93 0	93 2	94 5½
1923	94 6	104 9	122 0	126 10½	122 0	115 3	107 0	98 8½	98 10½	99 1½	100 6½	102 3	107 10½
1924	102 4½	101 3	99 7½	99 0	98 9½	97 4½	95 3½	93 1½	90 7½	88 0	88 4½	88 6	95 2½
1925	87 5	85 9	84 7½	82 6	80 10½	79 3	77 1½	75 7½	75 0	74 3½	74 9	76 0	79 5½
1926	77 3	77 9	77 3½	76 3	77 4½	78 0	79 8½	81 9	83 4½	87 7½	92 6	90 5½	81 7½
1927	90 "	90 0	86 3½	83 1½	80 6	78 0	76 6	75 4½	75 0	72 9	71 9	71 1½	79 2½
1928	69 7½	69 7½	69 9	70 0	70 0	69 3	68 7½	69 2	70 0	70 0	70 3	71 0	69 9½
1929	71 6	72 0	73 6	74 0	74 0	74 1½	74 9	75 6	76 1½	76 8½	78 1½	79 0	74 11½
1930	78 2½	78 0	76 9	75 0	74 0	72 7½	71 0	71 0	71 0	71 0	70 10½	70 4½	73 3½
1931	70 0	69 0	68 0	66 8½	65 1½	63 4½	62 9	61 1½	65 0	65 0	65 0	65 0	65 6
1932	64 10	64 3	63 6	63 6	63 6	62 7½	62 0	60 6	60 0	59 3	59 0	59 0	61 10
1933	59 0	59 0	59 0	59 0	59 0	59 0	59 0	59 0	59 3	60 7½	62 6	62 6	59 8½
1934*	62 6	65 0	67 6	67 6	67 6	67 6	67 6	67 6	68 0	68 6	68 6	68 6	67 2
1935*	69 0	69 0	69 0	69 0	69 0	69 0	70 1½	71 0	71 0	71 0	71 0	71 0	70 1
1936*	71 0	76 3	77 0	77 0	77 10½	80 6	—	—	—	—	—	—	—

* Since March, 1934, delivered works; previously f.o.t. furnaces.

WILLIAM JACKS & COMPANY,

WINCHESTER HOUSE, OLD BROAD ST., LONDON, E.C.2.

CLARENCE CHAMBERS, 39, CORPORATION STREET, BIRMINGHAM.

13, RUMFORD STREET, LIVERPOOL.

PIG IRON

REGISTERED TRADE MARK

FOR EVERY TYPE OF CASTING

NON-FERROUS METALS

REFRACTORIES — COKE — SAND

WILLIAM JACKS & COMPANY,

CENTRAL CHAMBERS, 93, HOPE ST., GLASGOW, C.2.

ZETLAND ROAD, MIDDLESBROUGH.

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SITUATIONS VACANT AND WANTED

EXPERT Foundry Manager, ferrous and non-ferrous, open to re-engagement; guarantee excellent results.—Apply Box 774, Offices of THE FOUNDRY TRADE JOURNAL, 49, Wellington Street, Strand, London, W.C.2.

FOUNDRY Foreman, with good practical and technical training, desires re-engagement; wide experience in all depts.; up to date with the latest methods.—Box 776, Offices of THE FOUNDRY TRADE JOURNAL, 49, Wellington Street, Strand, London, W.C.2.

FOUNDRY Foreman desires re-engagement. Has had sound practical experience in high-class engineering, capable organiser; excellent credentials.—Box 768, Offices of THE FOUNDRY TRADE JOURNAL, 49, Wellington Street, Strand, London, W.C.2.

LARGE Repetition Grey-Iron Foundry requires young Foundry Executive to train for position as Assistant Foundry Manager. Excellent opportunity for young man with initiative. Applicant must have had practical experience in moulding and general foundry work. Apply, giving full particulars of practical and technical training, to Box 770, Offices of THE FOUNDRY TRADE JOURNAL, 49, Wellington Street, Strand, London, W.C.2.

FOREMAN Patternmaker wanted for mechanised foundry producing light castings. Must be fully conversant with latest machine pattern-plate practice. State experience, age, salary required.—Box 766, Offices of THE FOUNDRY TRADE JOURNAL, 49, Wellington Street, Strand, London, W.C.2.

FOUNDRY Superintendent wanted. Modern methods, cupola practice, knowledge of alloy irons, sand control. Capable of producing castings ranging up to 40 tons. Some knowledge of non-ferrous work desirable also. Only men with the widest possible experience are eligible for this job. State age, salary, and full details of experience.—Box 762, Offices of THE FOUNDRY TRADE JOURNAL, 49, Wellington Street, Strand, London, W.C.2.

EMPLOYMENT REGISTER.

Conducted by the Institute of British Foundrymen by courtesy of the proprietors of THE FOUNDRY TRADE JOURNAL.

Correspondence should be addressed to the General Secretary, Institute of British Foundrymen, St. John Street Chambers, Deansgate, Manchester, from whom full particulars can be obtained of this service.

Any employer wishing to communicate with a candidate should write to the General Secretary, quoting identification number.

ASSISTANT Foundry Manager desires re-engagement. Experience includes in charge of highly mechanised plant, also general engineering jobbing experience. Fully competent to control metal mixtures, cupola management. Has had some laboratory experience. Sound technical training. (279)

FOUNDRY Manager requires position or as Assistant. Young, practical moulder, excellent experience in managerial positions on general engineering and also repetition work. Cupola control. Sound technical training. (281)

PROPERTY

MODERN Steelfoundry at Rotherham, main building 65 ft. by 150 ft. (erected 1916); complete with 10-ton crane. Site 1 acre. Siding on L.N.E. Rly. Adjacent canal.—Apply: GORDON, P.O. Box 98, Sheffield.

LARGE Iron-ore Mine, near Banbury, with rail sidings. Face of ore 16 ft. deep and 2 ft. below the surface. To be let on lease. For further particulars apply:—MESSRS. RAWLENCE & SQUAREY, 4, The Sanctuary, Westminster Abbey, London, S.W.

MACHINERY

NEW Dwarf Cupola, to melt 10 to 15 cwts. per hr. New Worm-geared Ladles, 5 tons, 25 cwts., 15 cwts. and 10 cwts. capacity. Ungeared Ladles, 15 cwts. and 10 cwts. capacity. Improved Cupola Spark Arresters.—T. DAVIES & SON, West Gorton, Manchester.

Tilghman Sandblast Barrel Plants; barrel sizes—60 in. x 40 in.; 36 in. x 20 in.; 20 in. x 30 in.

Tilghman Sandblast Cabinet Plants; 4 ft. 6 in. and 3 ft. 6 in. square (one for high pressure 70 lbs. per sq. in.); also small Cabinet 30 in. dia.

All complete with Air Compressors, etc.

Gas and Air Mixer by Sharpe & Preston, 2-in. outlet.

Six Osborne Pneumatic Jolt Press Moulding Machines, size 75J.

Three Mumford Yoke Headpress Pneumatic Moulding Machines.

Two Herbert Whizzer Sand Disintegrators.

Two Brealey Type ditto.

Heavy Double-ended Grinding Machines by Rowlands, Luke & Spencer, etc.

Hand Moulding Machines by Adaptable Darling & Sellars, Pridmore, Samuelson, etc.

500 Electric Motors, Dynamos, Rotary Converters, etc.

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CROSSWELLS ROAD (Adjoining Railway Crossing), LANGLEY, Nr. Birmingham.

'Phone: Broadwell 1359.

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"Pridmore" Pneumatic MOULDING MACHINE; type "EV"; take boxes 2′ 6″ x 1′ 9″.

Grimes hand-ram TURNOVER MACHINE; take boxes from 16″ square up to 26″ x 18″; 10″ clear draw.

Babcock W.T. Boiler of 4,356 sq. ft. heating surface; 150 lbs. w.p.

Write for "Albion" Catalogue.

Grams: "Forward." 'Phone: 23001 (10 lines).

ALBION WORKS, SHEFFIELD.

MISCELLANEOUS

FIRM of Ironfounders open to purchase grey-iron alloy specifications for high-duty irons; also receive offers of representative for sale of same.—Box 772, Offices of THE FOUNDRY TRADE JOURNAL, 49, Wellington Street, Strand, London, W.C.2.

TRY Southport Sand, the best for Cores. Quick deliveries by road. Any quantity. Sample free.

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SAND MERCHANT,
SOUTHPORT.

PATTERNS IN WOOD AND METAL for all branches of Engineering. Moulding methods carefully considered.—FURMSTON & LAWLOR, Letchworth.

MISCELLANEOUS—*Continued*

ENGINEERING Works, with modern foundry near Leeds, solicit inquiries for castings up to 8 tons in weight. Keen prices quoted.—Box 760, Offices of THE FOUNDRY TRADE JOURNAL, 49, Wellington Street, Strand, London, W.C.2.

'Phone: 287 SLOUGH

MOULDING MACHINES

Two Tabor Modern Jolt Squeeze and Pattern Draw Machines for boxes 20″ × 14″; as new. Price £65 each.

One ditto, for 20″ square Boxes. Price £70.

Several reconditioned GRIMES Hand Pattern-draw and Turnover Machines. Price £12 each.

One genuine OSBORN Hand Machine. Price £28.

Several nearly new DENBIGH Jolters. CHEAP!

CUPOLETTE, 30″ dia., NEW. Price £26.

PLEASE SEND US YOUR ENQUIRIES.

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14, AUSTRALIA ROAD, SLOUGH
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BIRMINGHAM, 12

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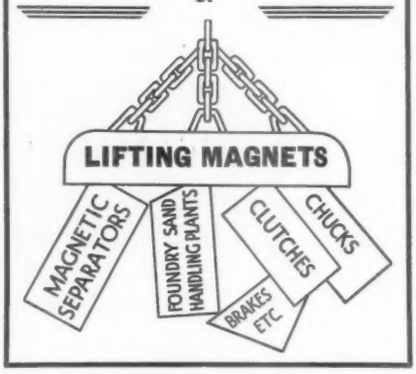

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